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# Rio Blanco Oil Shale Company

## MODULAR DEVELOPMENT PHASE MONITORING REPORT THIRTEEN

Volume 1 of 2

January – December 1983

Year End Report

Gulf Oil Corporation / Standard Oil Company (Indiana)
'A General Partnership'
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# RIO BLANCO OIL SHALE COMPANY
# MODULAR DEVELOPMENT PHASE
# MONITORING REPORT 13

January - December 1983
YEAR-END REPORT

Prepared by:
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AURORA, COLORADO

April 30, 1984

TABLE OF CONTENTS


| Section | Title | Page |
|---|---|---|
| 1 | INTRODUCTION | 1-1 |
| 2 | ATMOSPHERIC STUDIES | |
| 2.0 | Introduction | 2-1 |
| 2.1 | Air Quality | 2-3 |
| 2.2 | Meteorology | 2-21 |
| 2.3 | Climatology | 2-45 |
| 2.4 | Quality Assurance and Data Recovery | 2-54 |
| 2.5 | Visibility | 2-58 |
| 2.6 | Summary | 2-59 |
| 3 | TERRESTRIAL STUDIES | |
| 3.0 | Introduction | 3-1 |
| 3.1 | Vegetation | 3-2 |
| 3.2 | Fauna | 3-18 |
| 3.3 | Summary | 3-29 |
| 4 | AQUATIC STUDIES | |
| 4.0 | Introduction | 4-1 |
| 4.1 | Abiotic Components | 4-4 |
| 4.2 | Biotic Components | 4-16 |
| 4.3 | Summary | 4-26 |
| 5 | HYDROLOGY STUDIES | |
| 5.0 | Introduction | 5-1 |
| 5.1 | Dewatering/Reinjection/Discharge Program | 5-3 |
| 5.2 | MIS Modular Development Area | 5-24 |
| 5.3 | Summary | 5-72 |
| 6 | SPECIAL STUDIES/ECOLOGICAL INTERRELATIONSHIPS | |
| 6.0 | Introduction | 6-1 |
| 6.1 | Revegetation | 6-2 |
| 6.2 | Mule Deer Habitat Modification Study | 6-43 |
| 6.3 | Shrub Growth Enhancement on a Simulated Mine Site and/or Disposal Pile Bench | 6-45 |
| 6.4 | Study to Alter Natural Succession After Fire for Enhanced Deer-Livestock Forage | 6-61 |
| 6.5 | Comparison Study of Inhalable and Total Suspended Particulates | 6-67 |
| 6.6 | Summary | 6-75 |

LIST OF APPENDICES

Volume 2


| Appendix | Title |
|---|---|
| 2-0 | Atmospheric Studies |
| 2-1 | Air Quality Data |
| 2-1.1 | Plots of Gaseous Constituents Data at Site 1 |
| 2-1.2 | Total Suspended Particulate Data - Sites 1 and 3 |
| 2-2 | Meteorological Data |
| 2-2.1 | Plots of Meteorological Data at Site 1 |
| 2-2.3 | Precipitation Data |
| 2-2.4 | Snow Depth Data |
| 2-2.5 | Barometric Pressure Data |
| 3-0 | Terrestrial Studies |
| 3-2 | Mule Deer Studies |
| 3-2.1 | 1983 June Mule Deer Pellet Group Data |
| 4-0 | Aquatic Ecology Studies |
| 4-1 | Abiotic Monitoring |
| 4-1.1 | Stream Physical Data |
| 4-1.2 | Duncan's Multiple Range Test Results for an Analysis of Variance Model (Stream Physical Data) |
| 4-1.3 | Stream Water Chemistry Data |
| 4-1.4 | Duncan's Multiple Range Test Results for an Analysis of Variance Model (Water Chemistry Data) |

LIST OF APPENDICES (Continued)

Volume 2 (Continued)


| Appendix | Title |
|---|---|
| 4-2 | Biotic Data |
| 4-2.1 | Benthic Macroinvertebrate Count Data |
| 4-2.2 | Duncan's Multiple Range Test Results for Log Transformed Density Data |
| 4-2.3 | Duncan's Multiple Range Test Results for Log Transformed Density Data (Major Taxonomic Groups) |
| 5-0 | Hydrology Studies |
| 5-1.1 | 1983 Water Chemistry Data Listing (Alluvial Aquifers, Development Activities Monitoring, Springs and Seeps, and Upper Aquifer) |
| 5-1.2 | 1983 Field Measurements Data (Developmental Activities Monitoring, and Springs and Seeps) |
| 5-1.3 | 1983 Field Measurements Data (Alluvial Aquifers, Lower Aquifer, and Upper Aquifer) |
| 5-1.4 | 1983 Water Chemistry MANOVA Results (Dewatering/Reinjection/Discharge System, and MIS Development Area) |
| 5-2.1 | 1983 Water Year USGS Data (Stream Gage Sites) (Daily Values Time Series, Daily Field Measurements Data Listing, Water Chemistry Data Listing, and Duncan's Multiple Range Test Results - Daily Field Measurements, Duncan's Multiple Range Test Results - Water Chemistry Data) |

LIST OF APPENDICES (Continued)

Volume 2 (Continued)


| Appendix | Title |
|---|---|
| 6-0 | Special Studies/Ecological Inter-relationships |
| 6-1 | Experimental Revegetation Data and Analyses |
| 6-1.1 | Plot R-1 Experimental Revegetation Data |
| 6-1.2 | Analyses for Plot R-1 Experimental Revegetation Data |
| 6-1.3 | Plot R-2 Experimental Revegetation Data |
| 6-1.4 | Analyses for Plot R-2 Experimental Revegetation Data |
| 6-1.5 | Plot R-3 Experimental Revegetation Data |
| 6-1.6 | Analyses for Plot R-3 Experimental Revegetation Data |
| 6-3 | Shrub Growth Enhancement Studies |
| 6-3.1 | Shrub Growth Enhancement Studies Data |
| 6-3.2 | Analyses for Shrub Growth Enhancement Data |
| 6-4 | Yellow Creek Burn Habitat Modification Study |
| 6-4.1 | Cover Data |

# SECTION 1
# INTRODUCTION

# 1.0 INTRODUCTION

The United States Department of the Interior/Geological Survey (USGS) initiated planning in 1969 for a prototype oil shale leasing program. Under this program, Gulf Oil Corporation and Standard Oil Company (Indiana) acquired the rights to Federal Oil Shale Lease Tract C-a in the Piceance Basin in northwest Colorado in 1974. These two companies are developing Tract C-a under a general partnership called the Rio Blanco Oil Shale Company (RBOSC).

RBOSC has been engaged in extensive environmental data collection programs since its inception in 1974. Environmental baseline data were gathered between October 1974 and September 1976. An interim environmental monitoring program was conducted between September 1976 and August 1977, the period during which the Tract C-a lease was suspended. RBOSC initiated the Modular Development Phase (MDP) of tract development and the MDP Environmental Monitoring Program in August of 1977.

The MDP Environmental Monitoring Program is designed to provide data on air quality, meteorology, visibility, terrestrial ecology, aquatic ecology, hydrology, and specialized topics including ecological interrelationships. The program is designed based on the environmental stipulations in the Tract C-a lease, analysis of baseline and interim monitoring data, assessment of probable development impacts, and inputs from the BLM's Oil Shale Projects Office (OSPO). Monitoring is conducted according to the Lease Suspension Period Scope of Work (SOW), the current version of which (Revision 7.0) is dated January, 1983 and was approved by BLM's OSPO.

Data collected through the Environmental Monitoring Program are reported semi-annually, in a mid-year and a year-end report to the OSPO. The first MDP monitoring report (Modular Development Phase Environmental Monitoring Report One or MDP 1) was published in February 1978. Subsequent reports were published in September 1978, March and August 1979, March and August 1980, March and August 1981, April and September 1982, and April and

September 1983. This report is the thirteenth MDP Monitoring Report (MDP 13), and is the sixth year-end report. The MDP 13 report covers the 1983 reporting year (January 1 - December 31, 1983). The report contains presentations and summaries of 1983 data; statistical comparisons between seasons, years, and locations; and assessment of any development-related impacts. Sections of the report generally address objectives, methods, results and discussion, and summary and conclusions. Methods are referenced rather than fully described unless they are different from those employed in previous monitoring periods, need clarification, or have not been previously reported.

Major responsibility for implementation of the MDP monitoring program and preparation of the MDP reports rests with the staff of the RBOSC Environmental Affairs Department. Several other individuals and entities assisted in monitoring activities during the 1983 reporting period and in preparation of MDP 13, however. They include the following:

The Industrial Company (TIC) (Operational Hydrology Monitoring)

Chadwick and Associates (Aquatic Ecology Sample Analysis)

U.S. Geological Survey (Surface Water Gaging Station Data)

Cathedral Bluffs Shale Oil Company (Visibility Monitoring)

CORE Laboratories, Inc. (Water Quality Sample Analysis)

Volume one of MDP 13 contains the following major sections:

| | |
|---|---|
| Section 1 | Introduction |
| Section 2 | Atmospheric Studies |
| Section 3 | Terrestrial Studies |
| Section 4 | Aquatic Studies |
| Section 5 | Hydrology Studies |
| Section 6 | Special Studies/Ecological Interrelationships |

Volume two of MDP 13 contains the following appendices:

| | |
|---|---|
| Appendix 2 | Air Quality and Meteorological Data |
| Appendix 3 | Vegetation and Fauna Data and Analyses |
| Appendix 4 | Aquatic Abiotic and Biotic Data and Analyses |
| Appendix 5 | Hydrological Data and Analyses |
| Appendix 6 | Special Studies and Ecological Interrelationships Data and Analyses |

# SECTION 2
# ATMOSPHERIC STUDIES

## 2.0 INTRODUCTION

The Tract C-a atmospheric studies program consists of two elements: (1) measurements of total suspended particulate matter and certain gaseous chemical compounds, and (2) measurements of selected meteorological parameters. The monitoring locations were originally established to measure the ambient air quality generally upwind and somewhat removed from the expected tract development, and at points where tract developments might have an effect on the air quality. Simultaneous meteorological measurements are being made to allow for the prediction of the dispersion of emissions resulting from tract development.

Air quality and meteorological data have been obtained since February 1975 from monitoring instruments located on or near Tract C-a. Data collected during the first two years of monitoring make up the baseline data set. Data from the baseline period were obtained at four locations around the tract. Following the baseline period, an interim data acquisition program was established to cover an interval during which the tract development lease conditions were modified and partially suspended. During the interim period (February through August 1977), a single air quality and meteorological monitoring station was operated to maintain data continuity. The system was expanded to three meteorological and two air quality monitoring stations for the active Modified In-Situ (MIS) retorting stage of the Modular Development Phase.

Following completion of the MIS retorting program, activity on the tract has decreased to a very low level. The monitoring program has been reduced accordingly, and is essentially measuring background conditions. Currently, there is one air quality and meteorological monitoring site in operation (Table 2-1).

Table 2-1. Air Studies Monitoring Parameters and Schedule for 1983, Tract C-a

| Parameter | Location | Start Date | Frequency |
|---|---|---|---|
| Sulfur Dioxide | Site 1 | Feb. 1975 | Continuous |
| Hydrogen Sulfide | Site 1 | Feb. 1975 | Continuous |
| Nitric Oxide | Site 1 | Feb. 1975 | Continuous |
| Nitrogen Oxides | Site 1 | Feb. 1975 | Continuous |
| Ozone | Site 1 | Feb. 1975 | Continuous |
| Carbon Monoxide | Site 1 | Feb. 1975 | Continuous |
| Total Suspended Particulates | Sites 1,3 | Feb. 1975 | Every 4th Day |
| Wind speed (10m) | Site 1 | Feb. 1975 | Continuous |
| Wind speed (60m) | Site 1 | Feb. 1975 | Continuous |
| Wind direction (10m) | Site 1 | Feb. 1975 | Continuous |
| Wind direction (60m) | Site 1 | Feb. 1975 | Continuous |
| Wind sigma | Site 1 | Sept. 1981 | Continuous |
| Ambient temperature (10m) | Site 1 | Feb. 1975 | Continuous |
| Temperature differential (10-60m) | Site 1 | Feb. 1975 | Continuous |
| Precipitation | Sites 1, 3 | Feb. 1975 | By event |
| Snow depth and accumulation | Sites 1, 3 | Nov. 1978 | By event |
| Solar radiation | Site 1 | Feb. 1975 | Continuous |
| Visibility | Visibility Shelter | Spring 1978 | Semi-annually |

## 2.1 AIR QUALITY

Air quality monitoring is being conducted on and near Tract C-a to measure the concentrations of certain pollutants which may be emitted by tract operations. The ambient air quality monitoring network consists of one location where gaseous constituents are measured (Site 1) and two locations where total suspended particulate (TSP) concentrations are measured (Sites 1 and 3). Site 1 is located just west of the tract and generally measures background ambient air quality, while Site 3 is located east of the tract in a broad gulch that drains much of the tract. Under the minimum activity conditions of the lease suspension period, Site 3 will also measure primarily background particulate concentrations.

All of the air quality data, with the exception of the TSP data, are collected by automatic monitoring equipment and recorded by a data acquisition system on digital computer tape and backup strip charts. The data on the digital tape are recorded as hourly values. Hi-Vol monitors are used to collect 24-hour samples of TSP concentrations every third day.

A visibility study (in cooperation with Federal Oil Shale Lease Tract C-b) has been conducted each spring and fall since 1978 as part of the air studies program.

Plots of air quality data collected during 1983 are presented in Appendix 2-1.1.

As part of the year-end report, an extensive analysis has been carried out on the data obtained in 1983. Comparisons have been made among the current year, the baseline period (February 1975-January 1977), and the five previous years of the MDP period (1978, 1979, 1980, 1981 and 1982).

When analyzing a data set, it is important to evaluate the data in relation to the limitations of the instrumentation. This is particularly true of air quality data gathered in a pristine environment such as Tract C-a. Ambient

concentrations of several gaseous constituents usually are at or below the minimum measurement capability of air quality monitoring instruments. Statistical analyses may therefore not be applicable to these data sets.

A quantitative measure has been developed to use as a conservative minimum level, below which there is essentially no probability that the values represent real and valid data. This level, called the threshold of detection, is defined as twice the noise level of the instrument. The threshold of detection can thus be used to determine if there is a sufficient number of valid data points to warrant further statistical analyses.

It should be emphasized that the threshold of detection is a conservative measure to use in determining data validity. It is designed to take into account the errors or uncertainties which develop when measurements are taken near the minimum detectable limit of any monitor. These uncertainties are extremely difficult to quantify, but it is quite likely that the threshold of detection as defined above represents the instruments and data acquisition system in an optimal condition. Consequently, this value, determined independently for each instrument, is a conservative measure of data validity. That is, some data that are not significant (within the noise of the measurement system) may be retained, but no valid data will be arbitrarily discarded (due to a detection limit set too high).

The ultimate goal is to define confidence limits around the data collected by each instrument, which will serve as realistic criteria with which to judge the validity of the data. Threshold of detection values for each instrument are given in Table 2-2. These detection limits can be used as a guide to determine how much of the data can be considered valid for statistical analysis. The significance of the data for each parameter will be discussed separately in the appropriate sections below. In several

Table 2-2. Air Quality Instrumentation used at Tract C-a, with the Threshold of Detection for each Monitor

| Parameter | Manufacturer | Model | Technique | Threshold of Detection (ppm) |
|---|---|---|---|---|
| $SO_2$ | Thermo Electron Corporation | 43 | Pulsed Fluoresence | 0.002 |
| $H_2S$ | Thermo Electron Corporation | 45 | Pulsed Fluoresence | 0.002 |
| $NO/NO_x$ | Bendix | 8101-B | Chemiluminescence | 0.005 |
| Photochemical Oxidant ($O_3$) | Bendix | 8002 | Chemiluminescence | 0.001 |
| CO | Thermo Electron Corporation | 48 | Gas Filter Correlation Spectroscopy | 0.5 |

instances, the data sets are at or below the minimum detectable limit of the instrument, which limits the analysis that can be applied to the data.

## A. Sulfur Dioxide

### 1. Objectives

The objective of monitoring for sulfur dioxide is to establish the ambient air concentration prior to and during tract development. The existing sulfur dioxide levels and associated environmental effects can be used as a basis for assessing future environmental changes that may be related to any increase in the concentration of sulfur dioxide.

### 2. Methods

The methods followed for collection of sulfur dioxide data were described in RBOSC MDP Monitoring Report 5 (RBOSC 1980).

### 3. Results and Discussion

Table 2-3 provides mean, maximum, and minimum concentrations of air quality parameters monitored at Tract C-a during 1983. The table shows that the maximum hourly concentration of sulfur dioxide measured at Site 1 was 0.008 ppm, while the mean concentration was 0.002 ppm, at or below the threshold of detection of the instrument. Most of the sulfur dioxide concentrations monitored during the current year were at or below the threshold of detection for the instruments.

Comparison of the current year's data (Table 2-3) with data from earlier years (1982, Table 2-4; February 1975-January 1977, Table 2-5) show that yearly maximum and average sulfur dioxide concentrations have been similar in each of the years. The maximum hourly sulfur dioxide concentration in 1981 was 0.024 ppm. During the baseline period, the maximum concentration

Table 2-3. Summary of Air Quality Data Collected from January to December 1983, Tract C-a

| Parameter | Units | Minimum[1/] | Maximum[1/] | Arithmetic Mean |
|---|---|---|---|---|
| | | Site 1 | | |
| $SO_2$ | ppm | 0.002 | 0.008 | 0.002 |
| $H_2S$ | ppm | 0.002 | 0.007 | 0.002 |
| NO | ppm | 0.005 | 0.008 | 0.005 |
| $NO_x$ | ppm | 0.005 | 0.008 | 0.005 |
| $O_3$ | ppm | 0.015 | 0.073 | 0.042 |
| CO | ppm | 0.5 | 0.5 | 0.5 |
| TSP[3/] | $ug/m^3$ | 0 | 92 | 9 [2/] |
| | | Site 3 | | |
| TSP[3/] | $ug/m^3$ | 1 | 56 | 8 |

1/ Hourly Average

2/ Geometric Mean

3/ 24-hour Averages

Table 2-4. Summary of Air Quality Data Collected from January to December 1982, Tract C-a

| Parameter | Units | Minimum[1/] | Maximum[1/] | Arithmetic Mean |
|---|---|---|---|---|
| | | Site 1 | | |
| $SO_2$ | ppm | 0.002 | 0.024 | 0.003 |
| $H_2S$ | ppm | 0.002 | 0.012 | 0.003 |
| NO | ppm | 0.005 | 0.014 | 0.005 |
| $NO_x$ | ppm | 0.005 | 0.011 | 0.005 |
| $O_3$ | ppm | 0.016 | 0.078 | 0.043 |
| CO | ppm | 0.5 | 0.5 | 0.5 |
| TSP[3/] | $ug/m^3$ | 1 | 80 | 11 [2/] |
| | | Site 3 | | |
| TSP[3/] | $ug/m^3$ | 1 | 79 | 12 [2/] |

1/ Hourly Average

2/ Geometric Mean

3/ 24-hour Averages

Table 2-5. Summary of Air Quality Data Collected from February 1975 to January 1977 (Baseline Period), Tract C-a

| Parameter | Units | Minimum[1/] | Maximum[1/] | Arithmetic Mean |
|---|---|---|---|---|
| | | Site 1 | | |
| $SO_2$ | ppm | 0.000 | 0.09 | 0.01 |
| $H_2S$ | ppm | 0.000 | 0.05 | 0.01 |
| NO | ppm | 0.000 | 0.237 | 0.008 |
| $NO_x$ | ppm | 0.000 | 0.234 | 0.009 |
| $O_3$ | ppm | 0.000 | 0.068 | 0.034 |
| CO | ppm | 0.0005 | 4.2 | 0.6 |
| TSP[3/] | $ug/m^3$ | 1 | 211 | 9 [2/] |
| | | Site 3 | | |
| TSP[3/] | $ug/m^3$ | 1 | 79 | 15 [2/] |

1/ Hourly Average

2/ Geometric Mean

3/ 24-hour Averages

of 0.09 ppm was at least partially the result of less accurate and sophisticated instrumentation. The yearly means during both the baseline and MDP periods have been at or below the threshold of detection of the monitoring equipment.

B. Hydrogen Sulfide

1. Objectives

The objective of monitoring hydrogen sulfide in the ambient air on the tract is to establish the background value. Tract development, which will involve recovery of sulfur-bearing organics, may release hydrogen sulfide into the ambient air. Future concentrations of this constituent may be compared to pre-development conditions to assess environmental impacts.

2. Methods

The methods for collection of hydrogen sulfide data were described in RBOSC MDP Monitoring Report 5 (RBOSC 1980).

3. Results and Discussion

Table 2-3 shows that the maximum concentration of hydrogen sulfide at Site 1 during 1983 was 0.007 ppm. The mean annual concentration was 0.002 ppm, at or below the threshold of detection of the instrument. Comparisons with previous data show that the maximum concentrations have been low, while the mean annual concentrations have remained at or below the threshold of detection.

C. Oxides of Nitrogen

1. Objectives

Oxides of nitrogen are monitored to establish the existing natural background levels prior to major tract development and operation. Tract operations will involve substantial combustion during the retorting process with the resultant generation of oxides of nitrogen. Nitric oxide in the presence of sunlight and hydrocarbons may be a mechanism for smog production.

2. Methods

The methods followed for collection of oxides of nitrogen data were described in MDP Monitoring Report 2 (RBOSC 1978).

3. Results and Discussion

The concentrations of both nitric oxide and oxides of nitrogen were below the threshold of detection most of the time during the current year, resulting in a mean annual concentration of both these variables at or below 0.005 ppm. These values are similar to those obtained during previous years--no annual mean for either nitric oxide or oxides of nitrogen has exceeded 0.01 ppm. The maximum concentrations measured during 1983 were 0.008 ppm for both nitric oxide and oxides of nitrogen.

D. Carbon Monoxide

Carbon monoxide is produced by incomplete oxidation of carbon during combustion. Vehicular use and fuel combustion during tract development may result in the emission of carbon monoxide in the tract area.

1. Objectives

Carbon monoxide is monitored to establish the ambient air concentration of this constituent prior to and during tract development activities.

2. Methods

The methods followed for collection of carbon monoxide data were described in MDP Monitoring Report 2 (RBOSC 1978).

3. Results and Discussion

The measured concentration of carbon monoxide at Site 1 was at or below the threshold of detection most of the time. Both the maximum concentration and mean concentration during 1983 were 0.5 ppm. These results are very similar to those of previous years.

E. Ozone

1. Objectives

Ozone monitoring is conducted to determine the ambient air concentration of this constituent prior to and during tract development and operation. The potential emissions of oxides of nitrogen coupled with hydrocarbons in strong sunlight can produce photochemical reactions leading to the formation of ozone.

2. Methods

The methods followed for collection of ozone data were described in RBOSC MDP Monitoring Report 2 (RBOSC 1978).

3. Results and Discussion

The range of ozone concentrations recorded during 1982 at Site 1, as shown in Table 2-3, was 0.015 to 0.073 ppm. The mean concentration of ozone was 0.042 ppm. Thus, there were no violations of the primary or secondary National Ambient Air Quality Standard (NAAQS) for ozone (0.12 ppm). These concentrations are comparable to those found during the previous monitoring periods (Tables 2-4 through 2-5).

Previous year-end reports discussed the common phenomenon of relatively high concentrations of ozone occurring at remote sites such as Tract C-a. The conclusion, based on analysis of the site data and research done at other rural sites, was that these relatively high concentrations may be due to a number of factors, including stratospheric injection, photochemical reactions, or long-range transport. The concept of local production of ozone as an important factor to date has not been supported by the observed events.

F. Particulates

1. Objectives

The objectives of total suspended particulate (TSP) monitoring are to establish a natural background TSP concentration and to monitor the effects of tract development on TSP concentrations.

2. Methods

The methods followed for collection of TSP data were described in MDP Monitoring Report 4 (RBOSC 1979b).

3. Results and Discussion

Quarterly and annual geometric mean and maximum values of the TSP data for 1983 at each of the three sites are presented in Table 2-6. The highest

Table 2-6. Quarterly and Annual Geometric Means and Maximum Values of 24-hour Average Total Suspended Particulate Concentrations ($ug/m^3$) during 1983 on Tract C-a

| | Site 1 | Site 3 |
|---|---|---|
| Winter 1983 (Jan, Feb, Dec) | | |
| Geometric Mean | 4 | 4 |
| Maximum | 10 | 8 |
| Spring 1983 (March-May) | | |
| Geometric Mean | 7 | 6 |
| Maximum | 22 | 18 |
| Summer 1983 (June-August) | | |
| Geometric Mean | 17 | 20 |
| Maximum | 92 | 56 |
| Fall 1983 (September-November) | | |
| Geometric Mean | 8 | 10 |
| Maximum | 27 | 49 |
| 1983 Annual | | |
| Geometric Mean | 9 | 8 |
| Maximum | 92 | 56 |

Table 2-7. Quarterly and Annual Geometric Means and Maximum Values of 24-hour Average Total Suspended Particulate Concentrations ($ug/m^3$) during 1982 on Tract C-a

| | Site 1 | Site 3 |
|---|---|---|
| Winter 1982 (Jan, Feb, Dec) | | |
| Geometric Mean | 6 | 5 |
| Maximum | 17 | 18 |
| Spring 1982 (March-May) | | |
| Geometric Mean | 13 | 17 |
| Maximum | 48 | 52 |
| Summer 1982 (June-August) | | |
| Geometric Mean | 22 | 28 |
| Maximum | 80 | 79 |
| Fall 1982 (September-November) | | |
| Geometric Mean | 9 | 8 |
| Maximum | 20 | 32 |
| 1982 Annual | | |
| Geometric Mean | 11 | 12 |
| Maximum | 80 | 79 |

Table 2-8. Quarterly and Annual Geometric Means and Maximum Values of 24-hour Average Total Suspended Particulate Concentrations for the Baseline Period (February 1975 to January 1977) (ug/$m^3$) on Tract C-a

| | Site 1 | Site 3 |
|---|---|---|
| February 1975 | | |
| Geometric Mean | -- | 5 |
| Maximum | -- | 12 |
| Spring 1975 (March-May) | | |
| Geometric Mean | 29 | 23 |
| Maximum | 95 | 163 |
| Summer 1975 (June-August) | | |
| Geometric Mean | 22 | 47 |
| Maximum | 211 | 247 |
| Fall 1975 (Sep-Nov) | | |
| Geometric Mean | 6 | 18 |
| Maximum | 52 | 137 |
| Winter 1975-76 (Dec-Feb) | | |
| Geometric Mean | 2 | 4 |
| Maximum | 10 | 14 |
| Spring 1976 (March-May) | | |
| Geometric Mean | 11 | 11 |
| Maximum | 80 | 130 |
| Summer 1976 (June-August) | | |
| Geometric Mean | 22 | 27 |
| Maximum | 81 | 105 |
| Fall 1976 (Sep-Nov) | | |
| Geometric Mean | 12 | 35 |
| Maximum | 53 | 281 |
| Winter 1976-1977 (Dec-Jan) | | |
| Geometric Mean | 5 | 5 |
| Maximum | 18 | 59 |
| 1975-76 Annual | | |
| Geometric Mean | 9 | 18 |
| Maximum | 211 | 247 |
| 1976-77 Annual | | |
| Geometric Mean | 8 | 12 |
| Maximum | 81 | 281 |

24-hour concentration, 92 ug/$m^3$, was measured during the summer quarter at Site 1. This value is well below the 24-hour secondary National Ambient Air Quality Standard (NAAQS) for TSP of 150 ug/$m^3$. Annual geometric means for 1983 were 8 ug/$m^3$ at both sites. These values are far below the annual secondary NAAQS for TSP of 60 ug/$m^3$.

The quarterly and annual geometric means and maximum TSP concentrations for 1983 and the baseline period are presented in Tables 2-7 and 2-8 for comparison. The tables show that the geometric mean annual TSP at Site 1 decreased slightly from 1982 to 1983, from 11 to 8 ug/$m^3$. This is similar to the baseline data, which averaged 8 and 9 ug/$m^3$ during the two-year baseline period. These data reflect the low level of activity at the tract.

The geometric mean annual TSP concentrations at Site 3, located generally downwind of the tract development area, have been higher than the mean annual TSP concentrations at Site 1 for the entire period of record, even during the baseline period. However, during 1983, the annual mean TSP concentration at Site 3 was equal to the mean at Site 1. This is likely a result not only of the reduced activity on the tract, but also a reduction in the general activity in the area (e.g., less oil and gas drilling).

The annual cumulative frequency distributions of the TSP concentrations at both sites are presented in Figure 2-1. The distributions for Sites 1 and 3 are similar, except that the distribution for Site 3 is slightly higher at the high concentration end. The figure shows that the 50 percent probability points for the TSP concentrations in 1983 are 8 ug/$m^3$ for Site 1 and 7 ug/$m^3$ for Site 3. These are lower than the values obtained in 1982 of 11 ug/$m^3$ and 12 ug/$m^3$ for the same sites, respectively. The 50 percent probability concentrations obtained for the baseline period, 10 ug/$m^3$ for Site 1 and 22 ug/$m^3$ for Site 3, are similar to the 1983 data at Site 1 but considerably higher at Site 3.

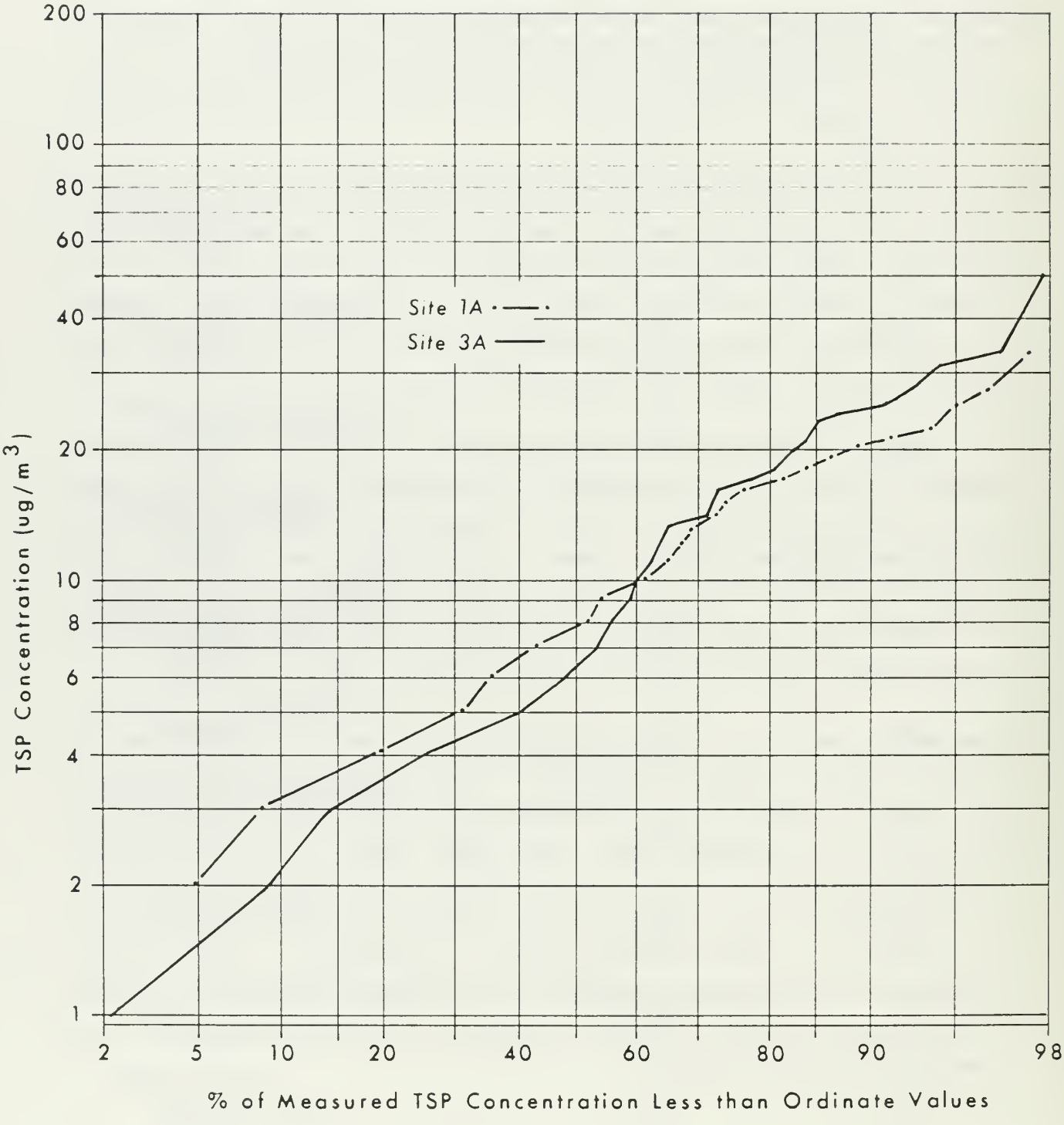



Figure 2-1. Cumulative frequency distributions of total suspended particulate (TSP) from the two tract C-a monitoring sites, January-December,1983.

Correlation Analysis

Table 2-9 provides the correlation coefficient (r) and the coefficient of determination ($r^2$) between sites for the TSP concentrations. The correlations were computed on an annual data set for each of the two baseline years and the five developmental years starting in 1979. The correlations between the two sites were lowest for the baseline years, and have increased to approximately 0.8 to 0.9 during the last four years. No rationale for the relatively low correlations during the baseline years has been developed.

The correlations for the current year are quite high, since the coefficient of determination given in Table 2-9 for Sites 1 and 3 ($r^2$ ) shows that 70 percent of the annual variation in TSP concentration at Site 1 is associated with the variations at Site 3. The similarity in the patterns of TSP concentrations appear to reflect primarily regional rather than localized influences. With the low activity levels in the area, the localized influences on TSP concentrations are probably minimal.

Table 2-9. Correlation Coefficients (r) and Coefficients of Determination ($r^2$) for the 24-hour Average Total Suspended Particulate Concentrations between Sites 1 and 3, Tract C-a

| Period | Correlation Between Sites 1 and 3 r | $r^2$ |
|---|---|---|
| Baseline | | |
| 2/75 - 1/76 | 0.31 | 0.10 |
| 2/76 - 1/77 | 0.49 | 0.24 |
| Modular Development Phase | | |
| 1979 | 0.60 | 0.36 |
| 1980 | 0.83 | 0.69 |
| 1981 | 0.85 | 0.72 |
| 1982 | 0.90 | 0.81 |
| 1983 | 0.83 | 0.70 |

The sample sizes for these correlations range from 72 to 115.

## 2.2 METEOROLOGY

Meteorological parameters are monitored to provide information on the general climate of Tract C-a and vicinity. They will also provide a basis for estimating the potential impact of emissions that may result from tract development and operation. One meteorological monitoring site was in operation during 1983. Meteorological data were taken at the 10-m and 60-m levels at Site 1. The parameters measured at this site are given in Table 2-1. Site 1 is at an elevation of 7,335 feet above mean sea level (MSL), and is located just west of the tract boundary. This section of the report deals primarily with the meteorological data collected during the period January-December 1983. Precipitation data and snow depth measurements are presented in Appendices 2-2.3 and 2-2.4, respectively. Barometric pressure data are presented in Appendix 2-2.5. The data for the baseline period and the previous years of the MDP period were extracted from earlier reports (RBOSP 1977, RBOSC MDP Monitoring Report 3, RBOSC MDP Monitoring Report 5, RBOSC MDP Monitoring Report 7, RBOSC MDP Monitoring Report 9, and RBOSC MDP Monitoring Report 11) for comparison purposes. Plots of meteorological data collected from continuous monitoring instruments are presented in Appendices 2-2.1 and 2-2.2.

### A. Temperature and Stability

#### 1. Objectives

Ambient air temperature, a primary climatic parameter, provides basic information on monthly and year-to-year variability of climatic conditions at Tract C-a. The measured vertical temperature differential within the lowest boundary layers is a measure of the stability of the atmosphere. Atmospheric stability strongly influences the dispersion of emissions into the atmosphere, and is therefore an important input into air quality models.

## 2. Methods

The methods followed for collection of temperature data were described in MDP Monitoring Report 3 (RBOSC 1979a).

## 3. Results and Discussions

Table 2-10 presents a summary of monthly, seasonal, and annual temperature statistics for 1983 on the tract (10-m level). The temperature statistics presented for each site include means, average daily maxima, average daily minima, absolute maxima, and absolute minima.

The mean annual temperature was 6.8 $^{o}$C at Site 1. Absolute maximum temperatures and absolute minimum temperatures at Site 1 were also very similar to earlier years. The extreme temperatures recorded at the tract during the current year were 29.0 $^{o}$C and -22.6 $^{o}$C.

The temperature record allows the calculation of the length of the frost-free period at each site. This information is helpful in determining the required hardiness and suitability of plants that will be used in revegetation of the tract. However, it should be noted that these temperatures are measured at 10-m above ground level, so that the first and last excursion below 0 $^{o}$C at 10-m (as used here) probably represents a "hard frost" at the ground surface.

Table 2-11 presents the frost-free period for the seven years at the two sites. The table also provides the 1980-1983 frost-free period for several climatological stations located in the vicinity of the tract. It should be noted that the National Weather Service stations measure the temperature at 2 meters, so the data are not strictly comparable to the data taken at the tract. However, they are included for reference.

Table 2-10. Monthly, Seasonal, and Annual Summary of Temperatures (°C) (Mean, Average Daily Maximum, Average Daily Minimum, Absolute Maximum, Absolute Minimum), January-December 1983, Level of Site 1 10-m Level, Tract C-a.

| Period | Mean | Avg Daily Max | Avg Daily Min | Abs Max | Abs Min |
|---|---|---|---|---|---|
| January | -1.4 | 1.6 | -4.3 | 7.1 | -12.0 |
| February | -1.5 | 1.7 | -4.4 | 8.2 | -11.4 |
| March | 0.4 | 3.5 | -2.6 | 11.4 | -11.4 |
| April | 1.5 | 5.2 | -2.3 | 15.4 | -12.0 |
| May | 8.3 | 12.8 | 3.8 | 20.9 | -2.3 |
| June | 14.6 | 18.8 | 10.5 | 25.5 | 2.7 |
| July | 19.2 | 23.9 | 14.4 | 28.9 | 7.1 |
| August | 20.4 | 24.9 | 15.8 | 29.0 | 12.6 |
| September | 16.0 | 20.7 | 11.0 | 26.9 | -4.6 |
| October | 9.1 | 12.9 | 5.5 | 16.8 | -0.4 |
| November | 0.5 | 4.0 | -2.5 | 16.2 | -12.1 |
| December | -5.7 | -2.3 | -9.3 | 4.1 | -22.6 |
| Seasonal | | | | | |
| Winter (Dec, Jan, Feb) | -2.9 | 0.3 | -6.0 | 8.2 | -22.6 |
| Spring (Mar, Apr, May) | 3.4 | 7.2 | 0.4 | 20.9 | -12.0 |
| Summer (Jun, July, Aug) | 18.1 | 22.5 | 13.6 | 29.0 | 12.6 |
| Fall (Sept, Oct, Nov) | 8.5 | 12.5 | 4.7 | 26.9 | -12.1 |
| Annual | 6.8 | 10.6 | 3.0 | 29.0 | -22.6 |

Table 2-11. Frost-free Period for Site 1 during the Period of Record, and the Frost-free Period During Recent Years for Selected Climatological Stations.

| | Frost-Free Period | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Site 1 | | Meeker | | Rangely | | Grand Junction | |
| Year | Length (Days) | Dates | Length (Days) | Dates | Length (Days) | Dates | Length (Days) | Dates |
| 1983 | 124 | 05/18-09/19 1/ | 98 | 06/14-09/20 | 125 | 05/18-09/20 | 206 | 04/17-11/09 |
| 1982 | 147 | 05/11-10/05 | 114 | 06/09-10/01 | M | M | 173 | 04/21-10/11 |
| 1981 | 156 | 05/13-10/16 | 118 | 06/16-10/12 | M | M | 202 | 04/06-10/25 |
| 1980 | 144 | 05/25-10/16 | 101 | 06/02-09/11 | 123 | 06/02-10/03 | 192 | 04/14-10/23 |
| 1979 | 133 | 06/09-10/20 | | | | | | |
| 1978 | 111 | 05/31-09/19 | | | | | | |
| 1976 | 112 | 06/14-10/04 | | | | | | |
| 1975 | 132 | 05/29-10/08 | | | | | | |

1/ Estimated due to lightning strike on tower during this period.

M = Missing data

The table shows that the frost-free period at Site 1 has ranged from 111 to 156 days over the eight years of record. The last frost date in the spring at the Tract is quite late, averaging around the last week in May. The first frost date in the fall ranges from mid-September to mid-October.

The frost-free periods at Meeker and Rangely are somewhat shorter than on the Tract (probably due to the difference in height above ground level that measurements are taken), but at Grand Junction the period is significantly longer. This is due at least partially to the lower elevation (4800 ft. at Grand Junction vs. 7300 ft. at Site 1).

Table 2-12 provides a summary of annual absolute minimum, absolute maximum, and mean values of the air temperature recorded at Site 1 during each of the eight years of data collected to date. There appears to have been no consistent trend during the period of record.

Atmospheric stability classifications (A-F), based upon temperature differences ($\Delta T$) within a short vertical distance of the surface, are based on recommendations by the Air Pollution Control Division of the Colorado Department of Health (1983). Other stability classification systems are based upon wind direction fluctuations, and will be presented in section 2.2(C). The most turbulent and unstable conditions are characterized by "A" stability, and the least turbulent and most stable conditions are characterized by "F" stability.

Table 2-13 presents the frequency distribution of stability classes by month and season for Site 1, based on data from 1983. Unstable (classes A, B, and C) conditions occurred predominantly during the summer and fall. Stable conditions, on the other hand, were most common during the winter.

Table 2-12. Summary of Annual and Combined Seven-Year Onsite Climatology of Absolute Minimum, Absolute Maximum and Mean Temperatures (C) During the Baseline and MDP Periods, Tract C-a.

| Temperatures[1/] | 2/75-1/76 | 2/76-1/77 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | Combined 8-Year Data Set |
|---|---|---|---|---|---|---|---|---|---|
| Site 1 (10-m level) | | | | | | | | | |
| Absolute Minimum | -21.1 | -21.7 | -24.0 | -24.6 | -15.5 | -19.9 | -26.2 | -22.6 | -26.2 |
| Absolute Maximum | 30.1 | 29.7 | 30.4 | 28.5 | 28.0 | 29.7 | 29.4 | 29.0 | 30.4 |
| Mean | 6.1 | 7.2 | 7.1 | 6.6 | 7.6 | 8.0 | 6.2 | 6.7 | 6.9 |

1/ Minimum and maximum annual temperatures are based on hourly average values for each 1-year period.

Table 2-13. Monthly, Seasonal, and Annual Occurrence (hours) of $\Delta T$ Stability Classes, January - December 1983, Site 1,Tract C-a

| Period | A | B | C | D | E | F | Total |
|---|---|---|---|---|---|---|---|
| January | 0 | 0 | 0 | 312 | 414 | 17 | 743 |
| February | 0 | 0 | 0 | 379 | 293 | 0 | 672 |
| March | 0 | 0 | 0 | 494 | 250 | 0 | 744 |
| April | 0 | 0 | 0 | 519 | 201 | 0 | 720 |
| May | 0 | 0 | 0 | 247 | 88 | 0 | 335 |
| June | 0 | 4 | 4 | 522 | 127 | 0 | 657 |
| July | 3 | 27 | 13 | 628 | 73 | 0 | 744 |
| August | 2 | 15 | 20 | 604 | 78 | 0 | 719 |
| September | 1 | 21 | 19 | 615 | 64 | 0 | 720 |
| October | 2 | 34 | 45 | 550 | 112 | 0 | 743 |
| November | 2 | 8 | 18 | 583 | 82 | 3 | 696 |
| December | 0 | 0 | 0 | 552 | 172 | 19 | 743 |
| Winter | 0 | 0 | 0 | 1243 | 879 | 36 | 2158 |
| Spring | 0 | 0 | 0 | 1260 | 539 | 0 | 1799 |
| Summer | 5 | 46 | 37 | 1754 | 278 | 0 | 2120 |
| Fall | 5 | 63 | 82 | 1748 | 258 | 3 | 2159 |
| Annual | 10 | 109 | 119 | 6005 | 1954 | 39 | 8236 |

B. Wind Speed and Wind Direction

1. Objectives

The wind speed and wind direction influence atmospheric dispersion. Measurement of the frequency of occurrence of wind speed and wind direction classes can also be used in interpreting air quality data.

2. Methods

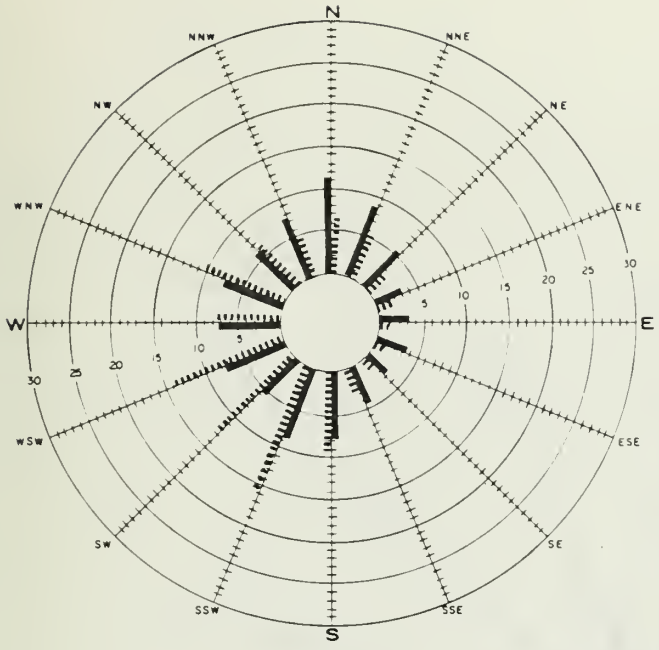
The methods followed for collection of wind data were described in MDP Monitoring Report 3 (RBOSC 1979a).

3. Results and Discussion

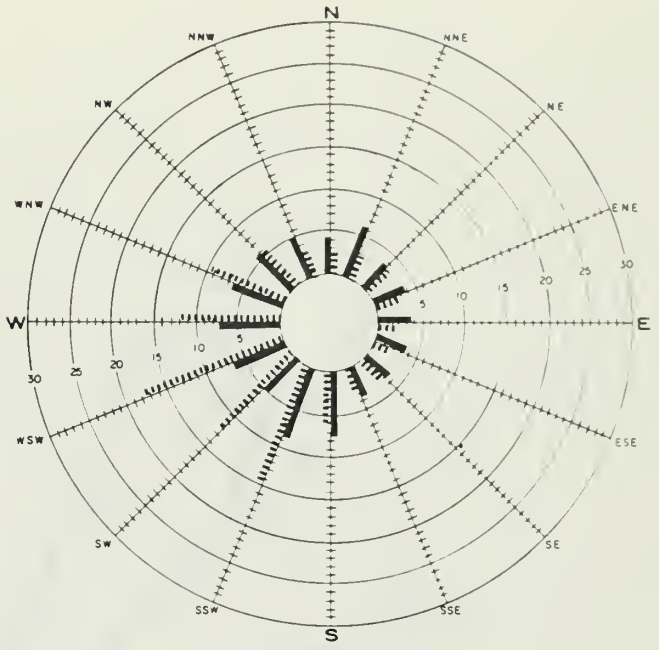
Seasonal and annual wind roses for each of the three sites for the current year are presented in Figures 2-2 to 2-5.

The Site 1 annual 10-m level wind rose for 1983 (Figure 2-3) shows the prevalent wind direction to be from the west-southwest (WSW on wind rose), with secondary maxima from the south-southwest (SSW), southwest (SW), and West (W). The mean wind speeds associated with these directions were 7.5, 8.1, 5.4 and 8.0 mph, respectively. The wind came from these four directions 56 percent of the time. These data compare well with the annual wind roses for the previous four years at this site, which all show the prevalent wind direction to be from the west-southwest. At Site 1, the wind directions with the lowest frequency of occurrence, as well as the lowest annual average wind speeds, were in the southeast quadrant during the entire data record.

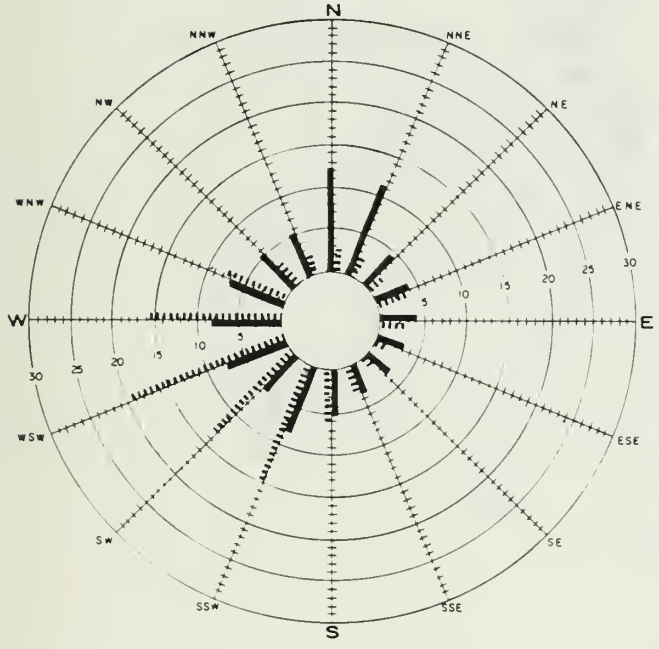
The Site 1 annual 60-m level wind rose for 1983 (Figure 2-5) shows the prevalent wind direction to be from the southwest, with secondary maxima from the west, west-southwest, and the south-southwest. The mean wind



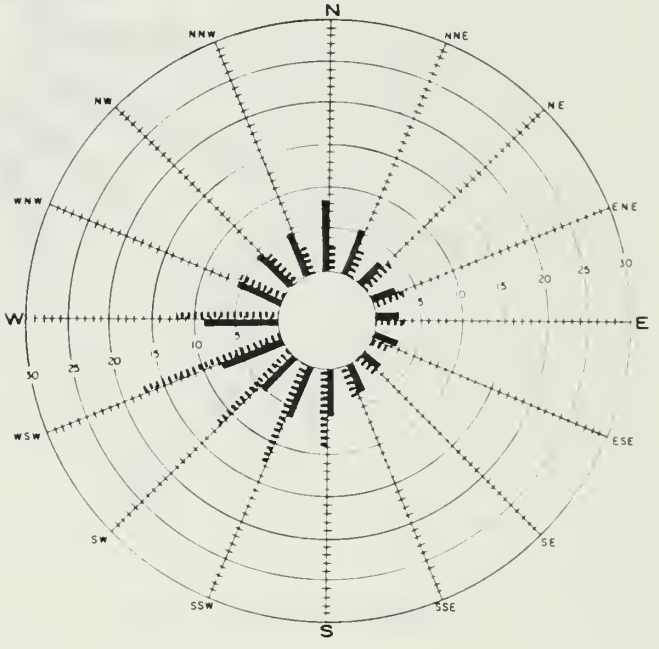

Spring




Summer




Autumn




Winter

Wind Speed (mph)
Wind Direction (%)

Figure 2-2. Seasonal Wind Roses, January-December 1983, Site 1, 10-m Level, Tract C-a.

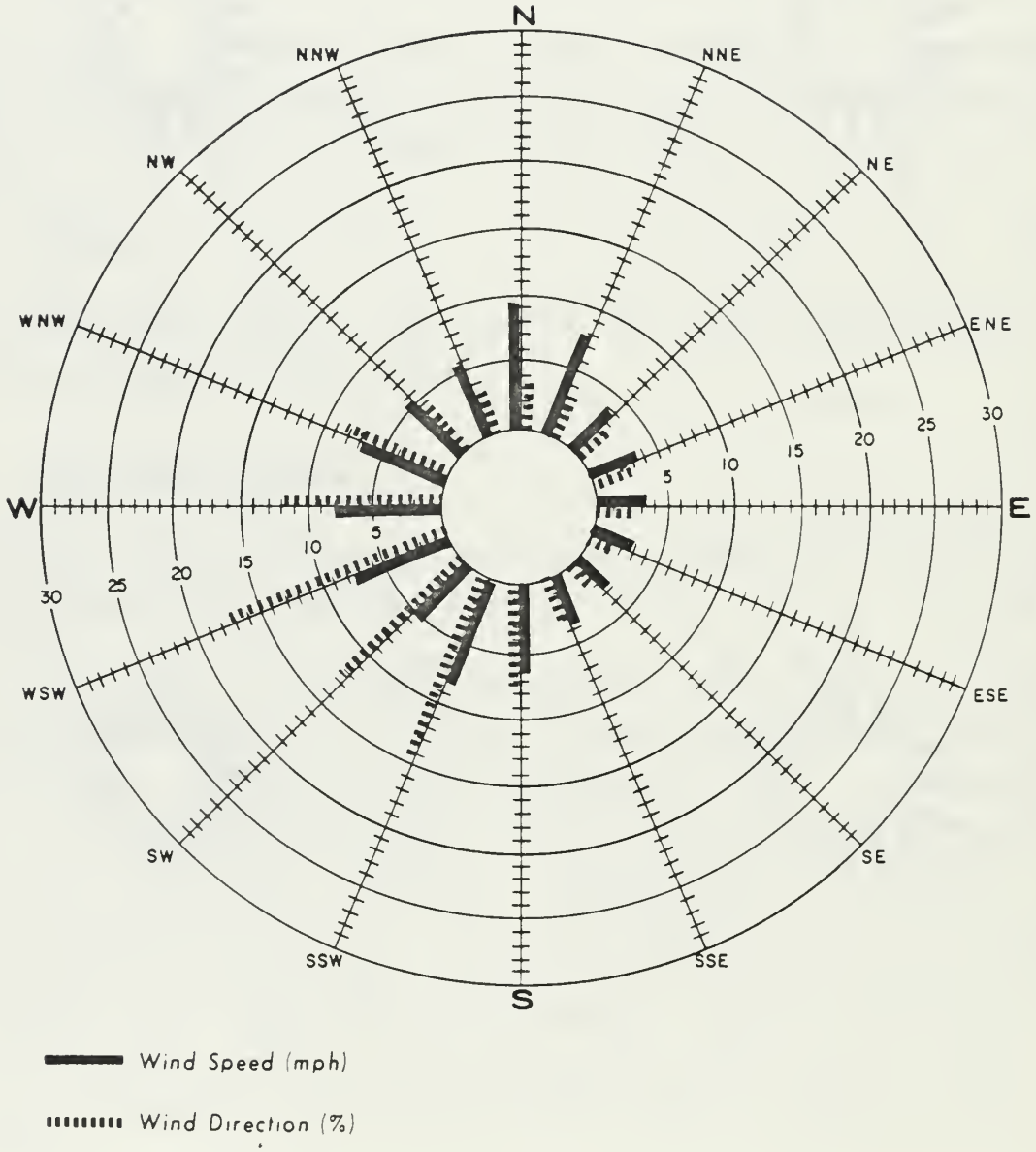
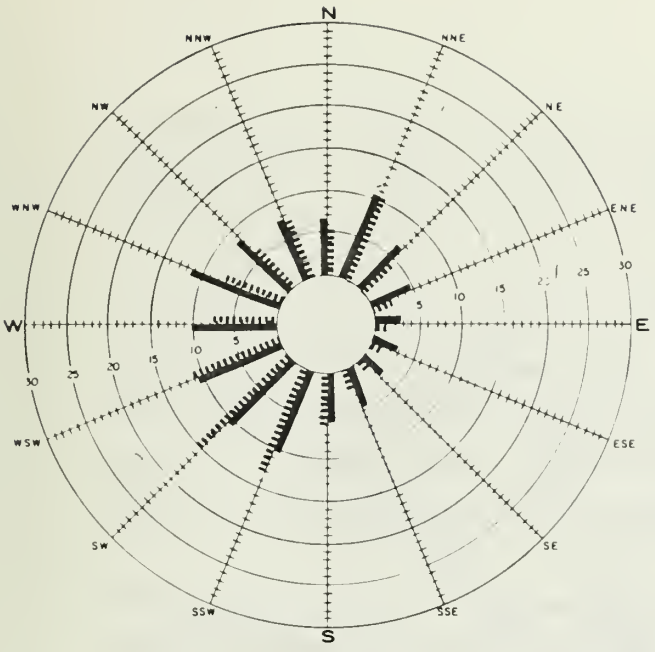
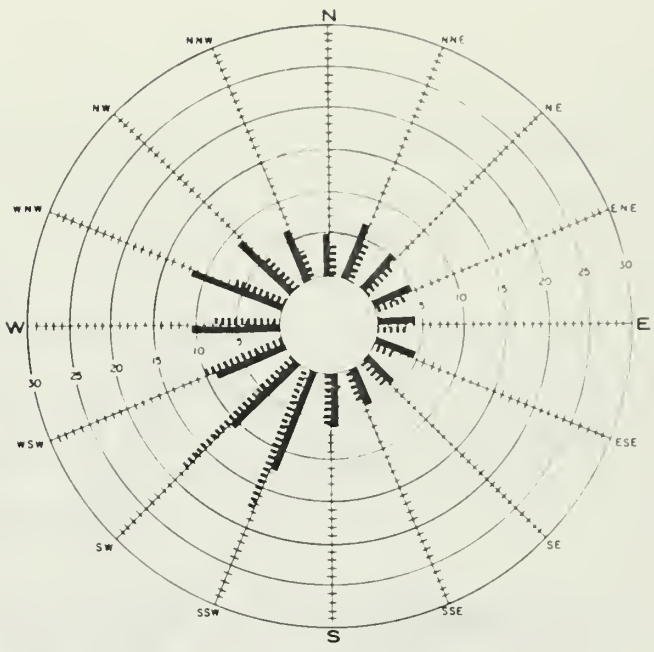


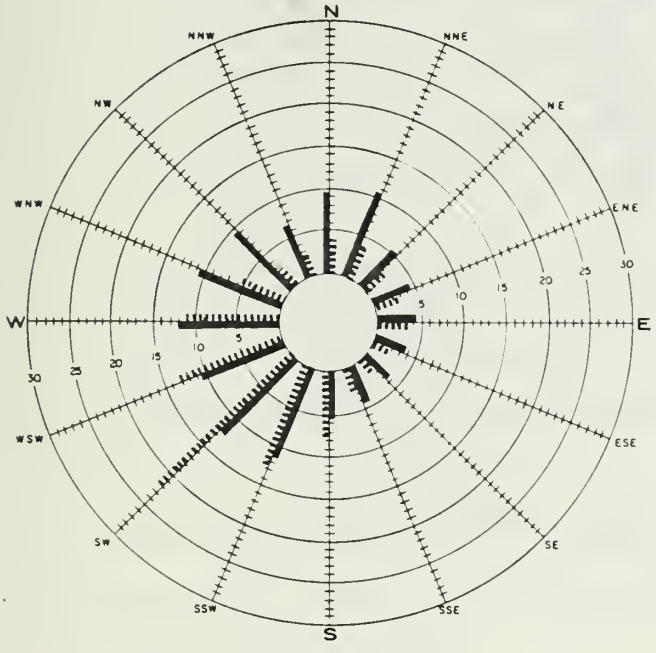

Figure 2-3. Annual Wind-Rose, January-December 1983, Site 1 10-m Level, Tract C-a.



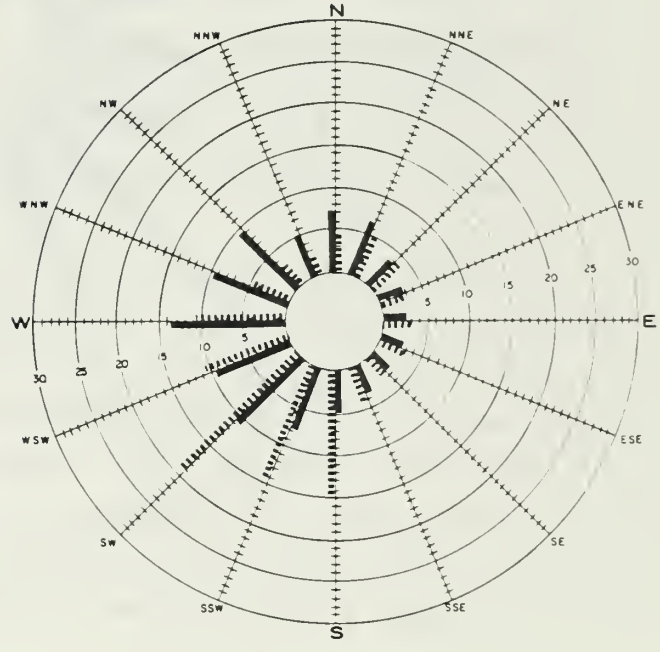

Spring




Summer




Autumn




Winter

Wind Speed (mph)
Wind Direction (%)

Figure 2-4. Seasonal Wind Roses, January-December 1983, Site 1, 60-m Level, Tract C-a.

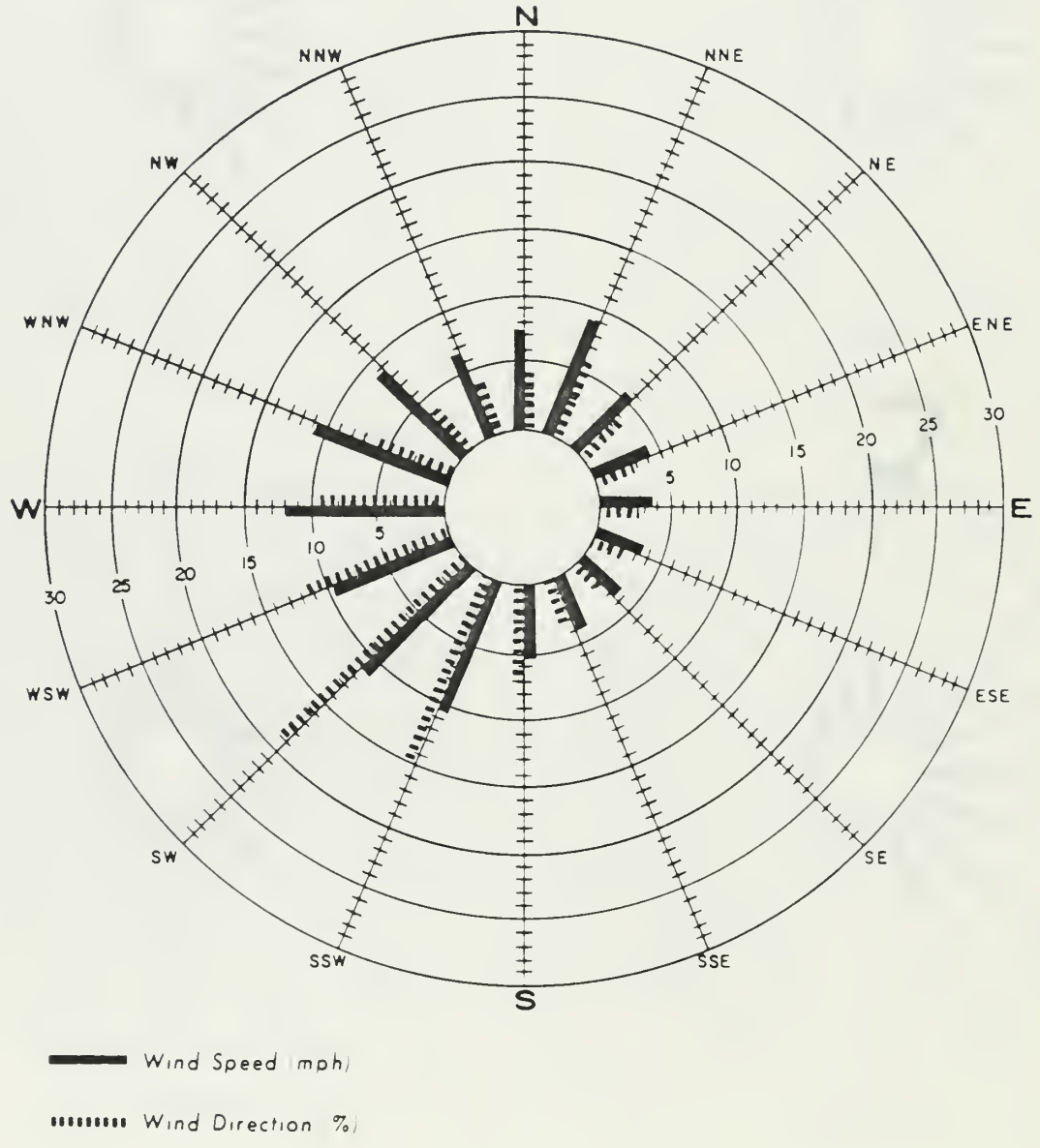



Figure 2-5. Annual Wind Rose, January-December 1983, Site 1 60-m Level, Tract C-a.

speeds associated with these directions were 11.1, 11.8, 9.9, and 10.5 mph, respectively. These data are similar to data from previous years, which also show the prevalent wind directions to be from the southwest.

Table 2-14 contains a summary of the absolute maximum and mean hourly wind speed recorded at the two sites during each of the data years. The mean wind speeds during the current year were 6.6 mph at the Site 1 10-m level and 8.9 mph at the Site 1 60-m level. There has been little variation in the mean wind speed during the period of record.

Tables 2-15 and 2-16 present the annual frequency of wind direction occurrences by hour for the two levels at Site 1 during the current year. These tables show the same data as given in the annual wind roses, but also illustrate the variation throughout the day. Each site shows the dominance of westerly winds. At Site 1 10-m level, for example, the wind blows from the five westerly 22.5$^{o}$ sectors (south-southwest through west-northwest) almost two-thirds of the time averaged over the day. The only exception to this in the early morning, when an upslope (easterly) wind flow is fairly common.

This morning upslope flow (caused by local solar heating of the terrain) can be shown by comparing the relative frequency of easterly winds at the 10-m level. During midafternoon, easterly winds (from the five 22.5$^{o}$ sectors northeast through southeast) occur approximately 14 percent of the time, and are present an average of only 5 percent of the time during the middle of the night. However, easterly winds occur 28 percent of the time at 0900 and 1000 hours, during the peak period of the upslope flow. The predominance of the westerly winds and the morning upslope flow are the major features of the surface wind regime.

Table 2-14. Summary of Annual and Mean Wind Speeds (mph) During the Baseline and MDP Periods, Tract C-a.

| Wind Speeds (mph)[1/] | 2/75-1/76 | 2/76-1/77 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | Combined 8-Year Data Set |
|---|---|---|---|---|---|---|---|---|---|
| Site 1 (10-m level) | | | | | | | | | |
| Maximum | 30.8 | 32.3 | 27.2 | 28.7 | 31.6 | 26.1 | 29.6 | 31.0 | 32.3 |
| Mean | 7.7 | 7.2 | 7.3 | 7.3 | 7.3 | 7.0 | 6.9 | 6.6 | 7.0 |
| Site 1 (60-m level) | | | | | | | | | |
| Maximum | 43.0 | 56.6 | 41.5 | 38.0 | 40.8 | 33.8 | 37.8 | 40.5 | 56.6 |
| Mean | 10.6 | 10.0 | 10.2 | 9.5 | 10.1 | 9.7 | 9.4 | 8.9 | 9.9 |

1/ Values based on hourly averages.

TABLE 2-15. WIND DIRECTION FREQUENCY (%) BY HOUR OF DAY, JANUARY TO DECEMBER 1983, 10 METER TOWER AT SITE 1, TRACT C-A

| HOUR | WIND DIRECTION | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | NNE | NE | ENE | E | ESE | SE | SSE | S | SSW | SW | WSW | W | WNW | NW | NNW |
| 1 | 2.3 | 2.3 | 0.9 | 0.6 | 0.9 | 0.9 | 1.2 | 3.8 | 6.1 | 8.8 | 16.7 | 21.9 | 15.2 | 10.2 | 5.6 | 2.6 |
| 2 | 4.4 | 1.5 | 0.9 | 0.9 | 0.6 | 0.9 | 1.8 | 0.6 | 7.3 | 12.6 | 18.1 | 19.3 | 13.7 | 8.5 | 6.7 | 2.3 |
| 3 | 2.9 | 1.2 | 1.2 | 1.2 | 0.6 | 0.6 | 2.0 | 3.2 | 4.7 | 13.2 | 15.5 | 22.2 | 9.9 | 11.7 | 5.8 | 4.1 |
| 4 | 4.1 | 1.5 | 1.5 | 1.5 | 0.3 | 0.6 | 0.3 | 1.8 | 6.4 | 10.5 | 15.5 | 24.0 | 13.2 | 9.4 | 5.8 | 3.8 |
| 5 | 3.8 | 1.2 | 1.2 | 0.9 | 1.2 | 1.5 | 1.5 | 2.6 | 6.5 | 10.6 | 15.8 | 19.1 | 14.1 | 10.6 | 5.6 | 4.1 |
| 6 | 3.2 | 0.9 | 2.6 | 0.9 | 0.3 | 1.5 | 0.9 | 3.2 | 5.0 | 10.6 | 17.3 | 24.3 | 11.1 | 10.3 | 5.6 | 2.3 |
| 7 | 4.7 | 1.2 | 2.1 | 1.5 | 0.6 | 1.5 | 2.3 | 5.3 | 9.1 | 13.2 | 11.7 | 16.7 | 10.9 | 8.8 | 6.5 | 4.1 |
| 8 | 2.9 | 3.2 | 5.6 | 5.0 | 4.4 | 2.6 | 4.4 | 5.8 | 12.9 | 13.5 | 7.6 | 12.0 | 8.2 | 5.3 | 2.9 | 3.8 |
| 9 | 3.2 | 3.8 | 3.8 | 9.9 | 6.7 | 3.8 | 4.1 | 4.7 | 12.9 | 12.6 | 8.5 | 12.6 | 5.0 | 2.9 | 2.9 | 2.6 |
| 10 | 1.8 | 4.7 | 7.0 | 9.1 | 7.6 | 2.6 | 2.6 | 5.8 | 8.2 | 15.8 | 7.0 | 13.2 | 7.0 | 3.5 | 2.3 | 1.8 |
| 11 | 1.5 | 4.7 | 6.7 | 7.0 | 6.7 | 2.3 | 2.6 | 3.2 | 9.1 | 17.6 | 7.6 | 11.7 | 10.3 | 3.5 | 1.8 | 3.5 |
| 12 | 5.0 | 5.0 | 3.8 | 7.3 | 2.3 | 1.8 | 1.2 | 2.3 | 8.5 | 16.7 | 8.8 | 15.8 | 12.0 | 3.2 | 3.5 | 2.6 |
| 13 | 4.1 | 6.1 | 3.2 | 5.0 | 3.8 | 1.8 | 1.8 | 1.8 | 7.3 | 18.4 | 8.5 | 16.1 | 12.6 | 4.7 | 3.2 | 1.8 |
| 14 | 3.2 | 4.4 | 5.6 | 3.5 | 2.6 | 1.8 | 0.3 | 1.8 | 7.6 | 19.0 | 8.5 | 12.6 | 16.7 | 5.3 | 4.1 | 3.2 |
| 15 | 3.2 | 5.8 | 3.8 | 4.7 | 2.0 | 0.9 | 1.7 | 0.6 | 9.6 | 17.8 | 8.7 | 11.4 | 13.7 | 8.7 | 5.8 | 1.5 |
| 16 | 3.5 | 4.9 | 2.6 | 3.8 | 3.2 | 1.2 | 2.6 | 1.4 | 7.8 | 19.7 | 7.8 | 10.1 | 15.1 | 9.0 | 4.6 | 2.6 |
| 17 | 3.5 | 4.1 | 2.6 | 2.3 | 2.6 | 1.2 | 1.4 | 2.6 | 7.8 | 19.1 | 9.3 | 11.9 | 9.3 | 11.0 | 6.4 | 4.9 |
| 18 | 4.1 | 3.5 | 2.3 | 1.2 | 1.4 | 1.4 | 1.7 | 2.6 | 8.7 | 19.7 | 9.6 | 11.0 | 11.0 | 9.6 | 6.7 | 5.5 |
| 19 | 4.3 | 3.8 | 1.7 | 0.9 | 0.9 | 0.6 | 0.3 | 4.6 | 5.8 | 18.3 | 12.8 | 16.8 | 9.6 | 10.1 | 7.0 | 2.6 |
| 20 | 2.6 | 4.1 | 1.2 | 1.2 | 0.9 | 0.3 | 2.0 | 2.9 | 6.7 | 10.1 | 16.2 | 20.3 | 13.3 | 9.9 | 6.1 | 2.3 |
| 21 | 3.8 | 2.0 | 0.9 | . | 0.9 | 0.9 | 0.9 | 4.3 | 6.4 | 9.3 | 16.5 | 22.9 | 12.8 | 11.0 | 4.6 | 2.9 |
| 22 | 3.5 | 2.9 | 0.9 | 0.3 | 0.3 | 1.2 | 1.7 | 1.2 | 4.7 | 12.2 | 18.0 | 20.6 | 12.2 | 11.3 | 5.2 | 3.8 |
| 23 | 3.2 | 3.2 | 1.7 | 0.6 | 0.6 | 1.2 | 0.6 | 1.5 | 5.8 | 10.5 | 15.7 | 21.8 | 16.9 | 9.3 | 4.1 | 3.5 |
| 24 | 3.2 | 1.5 | 2.3 | 0.9 | 0.3 | 0.6 | 1.2 | 1.7 | 3.8 | 13.1 | 15.7 | 24.2 | 15.5 | 9.6 | 4.7 | 1.7 |
| MEAN | 3.4 | 3.4 | 3.4 | 3.4 | 2.2 | 1.4 | 1.7 | 2.9 | 7.4 | 14.3 | 12.4 | 17.2 | 12.0 | 8.2 | 4.9 | 3.1 |

TABLE 2-16 . WIND DIRECTION FREQUENCY (%) BY HOUR OF DAY, JANUARY TO DECEMBER 1983, 60 METER TOWER AT SITE 1, TRACT C-A

| HOUR | WIND DIRECTION | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | NNE | NE | ENE | E | ESE | SE | SSE | S | SSW | SW | WSW | W | WNW | NW | NNW |
| 1 | 5.0 | 6.2 | 3.0 | 0.6 | 1.2 | 1.5 | 1.2 | 3.6 | 9.8 | 13.3 | 19.8 | 11.5 | 10.9 | 5.9 | 2.7 | 3.8 |
| 2 | 4.7 | 7.4 | 2.7 | 2.1 | 2.4 | 0.9 | 1.8 | 3.6 | 7.1 | 13.3 | 20.4 | 12.4 | 9.2 | 4.1 | 4.4 | 3.6 |
| 3 | 4.4 | 7.1 | 3.6 | 2.4 | 0.3 | 0.3 | 2.4 | 4.1 | 9.5 | 11.8 | 18.9 | 14.8 | 8.3 | 3.8 | 2.7 | 5.6 |
| 4 | 7.7 | 4.8 | 4.2 | 1.2 | 0.9 | 1.2 | 1.5 | 2.7 | 9.5 | 11.6 | 21.1 | 12.5 | 9.2 | 3.9 | 4.2 | 3.9 |
| 5 | 6.5 | 5.7 | 4.8 | 2.4 | 1.8 | 1.5 | 3.0 | 5.1 | 8.3 | 11.0 | 16.4 | 13.4 | 9.8 | 3.6 | 3.0 | 3.9 |
| 6 | 5.6 | 5.0 | 3.6 | 2.7 | 3.0 | 0.9 | 1.5 | 3.3 | 9.5 | 13.4 | 19.6 | 11.0 | 9.2 | 5.0 | 2.1 | 4.7 |
| 7 | 5.3 | 6.2 | 2.1 | 1.8 | 2.7 | 1.2 | 3.3 | 5.6 | 8.3 | 16.0 | 17.8 | 11.3 | 7.7 | 4.2 | 3.0 | 3.6 |
| 8 | 4.5 | 4.8 | 3.0 | 3.9 | 4.8 | 3.3 | 6.0 | 5.1 | 11.9 | 12.2 | 16.7 | 9.0 | 6.0 | 2.4 | 2.4 | 4.2 |
| 9 | 2.7 | 3.6 | 4.5 | 5.1 | 8.1 | 5.1 | 4.5 | 6.6 | 7.8 | 14.6 | 15.2 | 10.7 | 3.9 | 3.6 | 1.5 | 2.7 |
| 10 | 0.9 | 3.9 | 6.8 | 5.0 | 7.1 | 6.2 | 3.0 | 4.2 | 5.6 | 14.8 | 16.6 | 12.2 | 6.5 | 3.6 | 1.8 | 1.8 |
| 11 | 1.5 | 3.3 | 5.7 | 4.5 | 6.6 | 3.3 | 4.2 | 3.0 | 3.9 | 16.7 | 16.1 | 12.5 | 9.6 | 3.9 | 1.8 | 3.6 |
| 12 | 4.5 | 5.1 | 3.6 | 5.1 | 3.6 | 3.3 | 1.2 | 1.5 | 4.2 | 15.2 | 17.3 | 16.1 | 10.7 | 3.3 | 3.0 | 2.7 |
| 13 | 2.4 | 6.5 | 2.4 | 3.3 | 5.0 | 3.3 | 0.9 | 2.1 | 1.5 | 16.0 | 20.5 | 15.4 | 10.4 | 5.6 | 1.8 | 3.0 |
| 14 | 1.8 | 5.0 | 4.2 | 3.6 | 3.6 | 2.7 | 0.3 | 0.9 | 1.5 | 17.5 | 18.1 | 14.5 | 13.6 | 5.9 | 3.6 | 3.3 |
| 15 | 1.5 | 6.5 | 4.2 | 3.0 | 2.4 | 2.1 | 1.5 | 1.2 | 2.1 | 16.9 | 18.7 | 11.3 | 11.9 | 9.2 | 5.6 | 2.1 |
| 16 | 2.4 | 5.9 | 3.2 | 4.4 | 2.4 | 0.9 | 1.8 | 1.8 | 3.5 | 14.7 | 19.2 | 8.8 | 14.5 | 8.0 | 5.6 | 2.9 |
| 17 | 2.6 | 5.6 | 3.2 | 3.8 | 0.9 | 1.5 | 0.6 | 1.5 | 6.2 | 15.9 | 16.8 | 7.9 | 12.1 | 11.2 | 6.2 | 4.1 |
| 18 | 3.5 | 5.0 | 2.9 | 1.5 | 0.9 | 2.1 | 1.2 | 2.1 | 6.2 | 15.6 | 18.8 | 7.4 | 8.8 | 10.9 | 7.6 | 5.6 |
| 19 | 4.1 | 6.2 | 1.8 | 2.3 | 1.8 | 1.5 | 0.9 | 2.9 | 7.3 | 14.4 | 23.8 | 6.7 | 7.0 | 8.5 | 7.3 | 3.5 |
| 20 | 4.1 | 5.0 | 3.2 | 1.2 | 0.9 | 2.0 | 1.5 | 2.6 | 8.2 | 15.8 | 21.6 | 7.3 | 8.5 | 7.0 | 6.7 | 4.4 |
| 21 | 5.0 | 6.1 | 2.6 | 0.9 | 0.6 | 0.3 | 1.8 | 4.7 | 9.6 | 15.5 | 21.3 | 5.8 | 7.6 | 7.6 | 6.7 | 3.8 |
| 22 | 5.8 | 8.8 | 2.6 | 0.3 | 0.3 | 1.2 | 2.3 | 2.9 | 9.6 | 14.3 | 17.8 | 11.1 | 8.5 | 6.7 | 3.5 | 4.1 |
| 23 | 5.6 | 6.7 | 3.2 | 1.8 | 1.2 | 0.9 | 2.3 | 2.1 | 7.9 | 15.5 | 19.1 | 11.4 | 9.7 | 6.2 | 4.1 | 2.3 |
| 24 | 5.6 | 5.6 | 4.4 | 0.6 | 1.2 | 0.9 | 1.5 | 3.2 | 8.3 | 15.9 | 17.4 | 13.0 | 11.2 | 5.6 | 2.1 | 3.5 |
| MEAN | 4.1 | 4.1 | 4.1 | 4.1 | 2.6 | 2.0 | 2.1 | 3.2 | 7.0 | 14.7 | 18.7 | 11.2 | 9.4 | 5.8 | 3.9 | 3.6 |

Several additional methods for determining atmospheric stability involve measures of wind turbulence. Atmospheric stability estimation by temperature differential has recently been deemphasized in favor of stability estimation from wind measurements. Tables 2-17 and 2-18 present stability classes based upon the standard deviation of the horizontal wind direction fluctuations ($\sigma_\theta$), at the 10 and 60-m levels at Site 1, respectively. The calculations are based upon recommendations by the Air Pollution Control Division of the Colorado Department of Health (1983).

Comparison of Tables 2-17 and 2-18 ($\sigma_\theta$ stability) with Table 2-13 ($\Delta$T stability) reveals considerable differences in the distribution of stability classes. Based upon the calculation procedure recommended by the Department of Health, "D" stability (neutral) is much more common using $\Delta$T measurements than $\sigma_\theta$ measurements. D stability occurs 73 percent of the time based upon temperature differential, and 38 percent of the time based on the 10-m wind fluctuations. If D and E stability (neutral and slightly stable) conditions are combined, they occur 97 percent of the time using temperature differential, but only 53 percent of the time using the 10-m wind fluctuations. Thus, it appears that stability based upon horizontal wind fluctuation may be more realistic in defining stability classes.

## C. Precipitation

### 1. Objectives

Precipitation is recorded to provide data on the moisture availability for plant growth and revegetation.

### 2. Methods

The methods followed for collection of these data were described in MDP Report 2 (RBOSC 1978).

Table 2-17. Monthly, Seasonal, and Annual Occurrence (hours) of Stability Classes Based Upon the Site 1 10-m Horizontal Wind Direction Fluctuation ($\sigma_\theta$), 1983, Tract C-a

| | Stability Classes | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Period | A | B | C | D | E | F | G | Total |
| January | 33 | 36 | 77 | 284 | 213 | 44 | 56 | 743 |
| February | 35 | 63 | 87 | 257 | 168 | 35 | 27 | 672 |
| March | 39 | 60 | 103 | 297 | 194 | 35 | 16 | 744 |
| April | 80 | 81 | 118 | 224 | 160 | 37 | 17 | 717 |
| May | 37 | 35 | 56 | 120 | 36 | 10 | 7 | 301 |
| June | 109 | 112 | 134 | 162 | 117 | 52 | 31 | 717 |
| July | 135 | 102 | 126 | 183 | 118 | 41 | 39 | 744 |
| August | 177 | 84 | 79 | 145 | 143 | 44 | 47 | 719 |
| September | 82 | 111 | 105 | 200 | 138 | 45 | 37 | 718 |
| October | 86 | 77 | 100 | 197 | 172 | 60 | 51 | 743 |
| November | 37 | 71 | 77 | 235 | 150 | 40 | 56 | 666 |
| December | 48 | 50 | 70 | 279 | 151 | 60 | 85 | 743 |
| Winter | 116 | 149 | 234 | 820 | 532 | 139 | 168 | 2158 |
| Spring | 156 | 176 | 277 | 641 | 390 | 82 | 40 | 1762 |
| Summer | 421 | 298 | 339 | 490 | 378 | 137 | 117 | 2180 |
| Fall | 205 | 259 | 282 | 632 | 460 | 145 | 144 | 2127 |
| Annual | 898 | 882 | 1132 | 2583 | 1760 | 503 | 469 | 8227 |

Table 2-18. Monthly, Seasonal, and Annual Occurrence (hours) of Stability Classes Based Upon the Site 1 60-m Horizontal Wind Direction Fluctuation ($\sigma_\theta$), 1983, Tract C-a

| Period | Stability Classes | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | Total |
| January | 26 | 34 | 65 | 262 | 254 | 51 | 51 | 743 |
| February | 26 | 36 | 76 | 246 | 236 | 27 | 25 | 672 |
| March | 30 | 25 | 91 | 304 | 252 | 26 | 16 | 744 |
| April | 46 | 56 | 78 | 272 | 199 | 41 | 28 | 720 |
| May | 3 | 18 | 29 | 105 | 58 | 6 | 4 | 223 |
| June | 49 | 53 | 87 | 291 | 160 | 26 | 17 | 683 |
| July | 69 | 57 | 103 | 288 | 168 | 32 | 27 | 744 |
| August | 87 | 76 | 106 | 190 | 170 | 48 | 42 | 719 |
| September | 30 | 41 | 121 | 264 | 168 | 47 | 49 | 720 |
| October | 32 | 42 | 102 | 263 | 201 | 43 | 56 | 739 |
| November | 15 | 23 | 68 | 293 | 195 | 39 | 32 | 665 |
| December | 20 | 34 | 46 | 332 | 241 | 30 | 40 | 743 |
| Winter | 72 | 104 | 187 | 840 | 731 | 108 | 116 | 2158 |
| Spring | 79 | 99 | 198 | 681 | 509 | 73 | 48 | 1687 |
| Summer | 205 | 186 | 296 | 769 | 498 | 106 | 86 | 2146 |
| Fall | 77 | 106 | 291 | 820 | 564 | 129 | 137 | 2124 |
| Annual | 433 | 495 | 972 | 3110 | 2302 | 416 | 387 | 8115 |

## 3. Results and Discussion

Data from the three types of precipitation gauges for the period June-December 1983 are included in Appendix 2-2.3. Snow depth measurements taken during the current year are presented in Appendix 2-2.4. There is a substantial difference in the reported precipitation between the type of gauges installed at each site. The weighing bucket gauges generally have been recording somewhat higher precipitation amounts than the tipping bucket gauges. The wedge gauge data have been reasonably close to the results from the weighing bucket gauges.

Table 2-19 presents the monthly, seasonal, and annual precipitation at Sites 1 and 3 for the current year. The table is compiled from data which are collected by tipping bucket, weighing bucket, and wedge gauges. Precipitation measured at the three sites during the current year ranged from 15.84 to 20.96 inches. Although the natural variability of precipitation is high in semi-arid regions, a substantial part of the range in values is probably due to different exposures and capture efficiencies of the gauges.

The weighing bucket gauges are thought to produce the most representative precipitation data, due to a better exposure and the improvement in winter capture efficiency through the use of snow shields. The tipping bucket gauges have historically recorded lower amounts of precipitation than other gauges, which may be due to a less efficient capture and measurement technique (RBOSC 1980).

Table 2-20 presents the results of the precipitation measurements collected onsite over the past six years. The table shows that 1983 was the wettest year during the entire period of record. The best estimate of annual precipitation, based on data from the weighing bucket gauges, indicates that precipitation totalled approximately 13 inches in 1978 and 1979, 12 inches in 1980, 17 inches in 1981, 16 inches in 1982 and 21 inches in 1983.

Table 2-19. Monthly, Seasonal, and Annual Precipitation (inches) at Sites 1 and 3 from available Tipping Bucket Gauge, Weighing Bucket Gauge, and Wedge Gauge Data at Tract C-a for the period January - December 1983.

| Month | Site 1 | | | Site 3 |
|---|---|---|---|---|
| | Tipping Bucket Gauge | Weighing Bucket Gauge | Wedge Gauge | Wedge Gauge |
| January | 0.19 | 0.41 | 0.35 | 0.25 |
| February | 0.44 | 0.83 | 0.68 | 0.62 |
| March | 1.36 | 2.10 | 1.59 | 1.63 |
| April | 1.74 | 2.31 | 1.82 | 1.77 |
| May | 3.50[1/] | 4.54 | 3.68 | 3.32 |
| June | 1.14 | 1.13 | 1.24 | 1.43 |
| July | 0.93 | 1.16 | 1.23 | 1.25 |
| August | 0.70[1/] | 0.75 | 0.90 | 1.15 |
| September | 0.73 | 0.82 | 0.93 | 0.99 |
| October | 1.92 | 2.26 | 2.38 | 1.61 |
| November | 1.75 | 2.57 | 1.78 | 1.48 |
| December | 1.42 | 2.08 | 2.34 | 1.79 |
| Seasonal | | | | |
| Winter (Dec, Jan, Feb) | 2.05 | 3.32 | 3.37 | 2.66 |
| Spring (Mar, Apr, May) | 6.60 | 8.95 | 7.09 | 6.72 |
| Summer (Jun, July, Aug) | 2.77 | 3.04 | 3.37 | 3.83 |
| Fall (Sep, Oct, Nov) | 4.40 | 5.65 | 5.09 | 4.08 |
| Annual | 15.82 | 20.96 | 18.92 | 17.29 |

1/ Estimated due to instrumentation problems.

Table 2-20. Summary of Precipitation Measurements (inches) During the Past Six Years at Tract C-a

| | 1978 | | 1979 | | 1980 | | 1981 | | 1982 | | 1983 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gauge | Site 1 | Site 3 | Site 1 | Site 3 | Site 1 | Site 3 | Site 1 | Site 3 | Site 1 | Site 3 | Site 1 | Site 3 |
| **Tipping Bucket** | | | | | | | | | | | | |
| Winter | -- | -- | 0.81 | 0.90 | 1.86 | 1.46 | 0.75 | -- | 1.02 | NA | 2.05 | NA |
| Spring | -- | 3.33 | 3.66 | 3.95 | 3.83 | 3.73 | 3.34 | 3.34 | 2.00 | | 6.60 | |
| Summer | -- | 1.58 | 2.38 | 1.71 | 2.65 | 3.52 | 4.29 | -- | 2.55 | | 2.77 | |
| Fall | 1.63 | -- | 2.93 | 2.15 | 0.98 | 1.61 | 4.87 | 4.00 | -- | | 4.40 | |
| Annual | -- | -- | 9.78 | 8.71 | 9.32 | 10.32 | 13.25 | -- | -- | | 15.82 | |
| **Weighing Bucket** | | | | | | | | | | | | |
| Winter | 4.15 | NA | 2.24 | NA | 2.27 | NA | 1.92 | NA | 2.59 | NA | 3.32 | NA |
| Spring | 5.15 | | 6.06 | | 5.25 | | 3.61 | | 3.05 | | 8.95 | |
| Summer | 1.71 1/ | | 2.17 | | 2.56 | | 4.69 | | 3.08 | | 3.04 | |
| Fall | 3.21 | | 3.28 | | 1.52 | | 6.59 | | 7.64 | | 5.65 | |
| Annual | 14.22 | | 13.75 | | 11.60 | | 16.81 | | 16.36 | | 20.96 | |
| **Wedge** | | | | | | | | | | | | |
| Winter | 3.28 | 2.29 | 1.50 | 1.76 | 2.52 | 1.83 | 1.85 | 1.44 | 2.25 | 1.63 | 3.37 | 2.66 |
| Spring | 4.27 | 3.98 | 5.44 | 4.16 | 4.99 | 4.96 | 4.91 | 4.14 | 3.01 | 2.77 | 7.09 | 6.72 |
| Summer | 1.82 | 1.57 | 2.28 | 1.95 | 3.25 | 3.43 | 5.14 | 6.09 | 3.23 | 2.63 | 3.37 | 3.83 |
| Fall | 2.94 | 2.43 | 2.15 | 2.38 | 2.24 | 6.44 | 5.73 | 3.91 | 7.80 | 5.91 | 5.09 | 4.08 |
| Annual | 12.31 | 10.16 | 11.65 | 10.32 | 13.14 | 12.22 | 18.34 | 15.58 | 16.28 | 12.94 | 18.92 | 17.29 |

1/ Estimated.

The wettest month during 1983 was May, when approximately 22 percent of the total annual precipitation fell. During 1982, the wettest month was September, when 25 percent of the total annual precipitation fell. The wettest season in 1978, 1979, 1980 and 1983 was spring, but it was fall in 1981 and 1982. As expected in a semi-arid region, both the total precipitation and the period of greatest precipitation are highly variable.

## D. Solar Radiation

### 1. Objective

Solar radiation is monitored to supplement the data base for interpreting the meteorological and air quality data.

### 2. Methods

The methods followed for collection of these data were described in MDP Monitoring Report 4 (RBOSC 1979b).

### 3. Results and Discussion

Table 2-21 presents the maximum and mean (based on daylight hours only) monthly solar radiation at Site 1 for the current year. Due to lightning damage to the instrument in late 1982, several months of solar radiation data in early 1983 were lost. The average solar radiation during daylight hours was calculated to be 0.53 ly/min, but this number is probably biased on the high side due to missing data in January, February, and March. A more representative value (based upon substitution of 1982 data for the missing data in 1983) would be 0.50 ly/min.

Table 2-21. Maximum and Mean Solar Radiation (ly/min) at Site 1, January-December 1983, RBOSC Tract C-a

| Month | Maximum[1/] Solar Radiation (ly/min) | Mean[1/] Solar Radiation (ly/min) |
|---|---|---|
| January | -- | -- |
| February | -- | -- |
| March | -- | -- |
| April | 1.44 | 0.60 |
| May | 1.55 | 0.64 |
| June | 1.46 | 0.62 |
| July | 1.48 | 0.62 |
| August | 1.37 | 0.62 |
| September | 1.28 | 0.61 |
| October | 1.05 | 0.45 |
| November | 0.98 | 0.34 |
| December | 0.75 | 0.25 |
| Season | | |
| Winter | -- | -- |
| Spring | 1.55 | 0.62 [2/] |
| Summer | 1.46 | 0.62 |
| Fall | 1.28 | 0.47 |
| Annual | 1.55 [3/] | 0.53 [3/] |

1/ Maximum and mean values computed from hourly average during daylight hours.

2/ Based on data from two months

3/ Based on data from nine months

## 2.3 CLIMATOLOGY

This section presents a description of the general climatology of the region in which Tract C-a is located.

### 1. Objectives

It is the intent to develop a climatology by comparing meteorological data collected from the RBOSC site (defined as "onsite") with both short-term and long-term climatic data available from other meteorological stations in the region. The rugged topography of western Colorado causes variations in climate within short distances, and caution must be used when applying climatic generalizations to the whole area. Ideally, the most accurate way of characterizing the climatology of Tract C-a is to develop a long-term meteorological data base from data gathered onsite. The available onsite meteorological data base of eight years cannot be construed as being representative of the long-term climatic conditions in the tract area; however, the onsite data can be compared with similar short-term and long-term data in the region to identify site-specific climatic conditions due to elevation, exposure, and the orientation of mountain ranges and valleys.

### 2. Methods

The methods followed for collection of climatological data were described in MDP Monitoring Report 3 (RBOSC 1979a).

### 3. Results and Discussion

Figure 2-6 presents the sources of climatological data in the northwest section of the State of Colorado, where Tract C-a is located at an average elevation of 7000 feet above Mean Sea Level. The weather station closest to the tract is Little Hills, located 15 miles to the northeast at an elevation

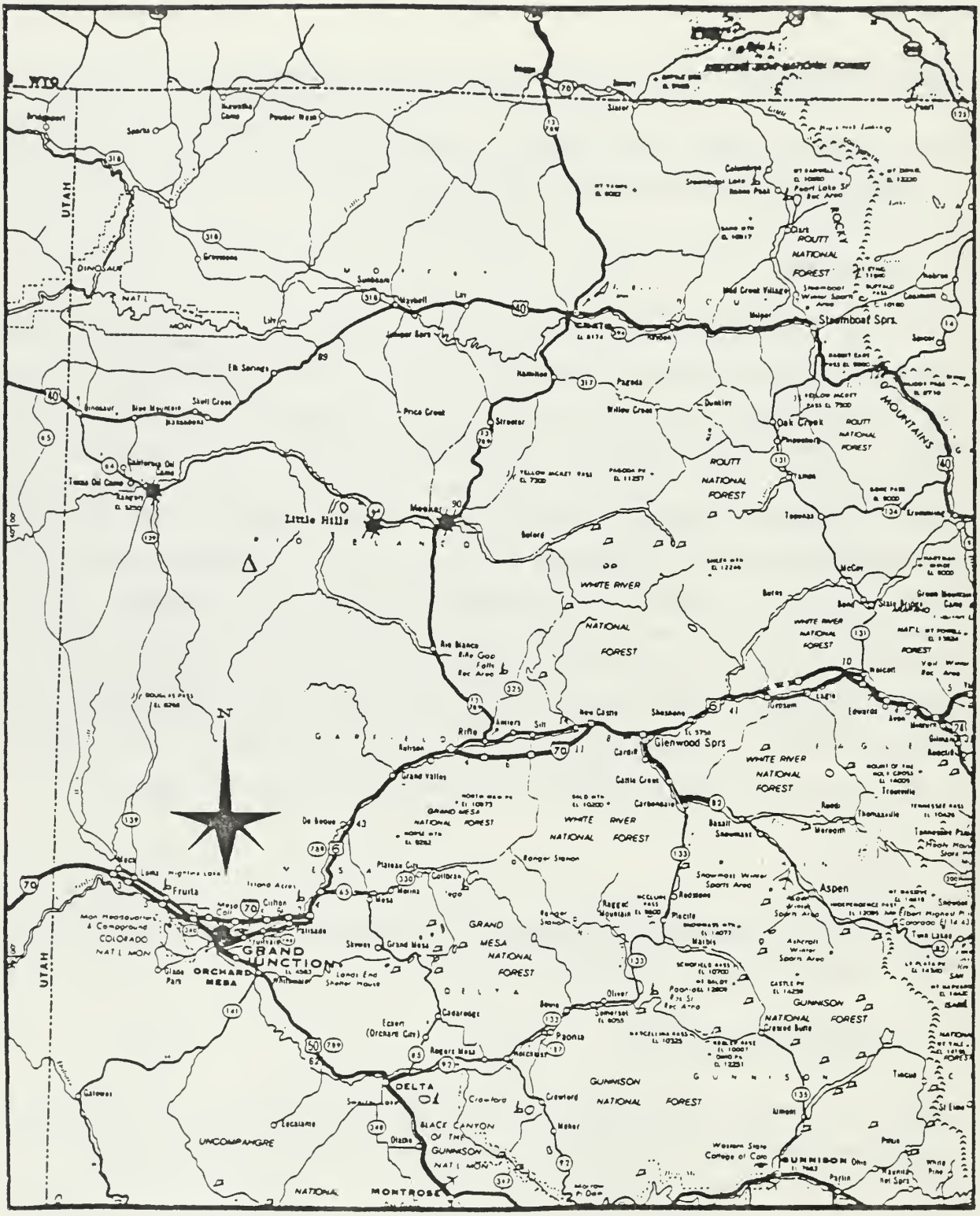



Figure 2-6. Map of Northwest Colorado Showing the Rio Blanco Region.

of 6140 feet. The Meeker No. 2 station is located about 30 miles to the east-northeast at an elevation of 6350 feet. The Rangely station is located about 20 miles to the west-northwest at an elevation of 5220 feet. Grand Junction, at an elevation of 4843 feet, is about 60 miles south of the site. All of these stations monitor temperature and precipitation. At Grand Junction other parameters are measured as well.

The following is a discussion of the climatology of the area and the influences of the topography on the general meteorological and climatic conditions in the area. It has been extracted from the Final Environmental Baseline Report (RBOSP 1977):

> The Tract C-a area is surrounded by high mountains. As a result, many migratory low pressure systems are deflected around the region. Stationary high-pressure cells often persist for several days, their passage blocked by the Continent Divide east of Tract C-a. As a result, there is a high frequency of clear sunny days with light winds and large diurnal temperature changes. Gradient winds are generally westerly, existing throughout the year, except when interrupted by the passage of frontal systems. Precipitation measurements indicate relatively low annual accumulations such as those of semi-arid steppe regions. In addition, the data indicate a high degree of temporal and spatial variability in this area, which is to be expected given the rough terrain with its variations in elevation and exposure. The infrequent occurrences of precipitation , fog, and small light-scattering airborne dust have produced excellent visibility, in general, for the Tract C-a area.
>
> Local topography within the Tract C-a area has a much more pronounced effect on surface flows than the macroscale processes. Specific air movements produced by local conditions are often different from those expected from the major gradient flow. There is a tendency for wind velocities to be lowest at sunrise, when there is little vertical thermal mixing and the lower surface air does not couple with the more freely moving upper air. Conversely, velocities of local winds are greatest in the early afternoon hours when the air exhibits its greatest tendency to move vertically due to terrestrial heating, and couples with the faster air moving above it.

In the absence of strong gradient winds, the local terrain produces special meteorological conditions. During warm afternoon hours, the laterally constricted, but vertically expanding, air tends to flow up the valley. This air motion probably develops simultaneously with anabatic (upslope) winds which result from a greater heating of the valley sides than the valley floor. At night, the reverse process occurs with the cold, dense air at higher elevations draining into the depressions. The greater radiative heat loss affecting the higher elevations (especially if they are snow-covered) cools the air immediately adjacent to the surface, and this air sinks into the valley. Downward flowing cold air set in motion by this effect forms downslope winds leading to an accumulation of cold, dense, stable air in the valley bottom.

The high Cathedral Bluffs to the west of Tract C-a and the deep gulches to the east effectively channel surface winds, and thereby decouple the upper level flows from the surface flows much of the time. Several studies have shown that airflow within the canyons of the Piceance Creek and Yellow Creek Basins is influenced by drainage winds in their respective channels, whereas winds measured atop the ridge-like portions of the basin closely follow the gradient wind regime. It can be inferred that these drainage winds occur in conjunction with stronger temperature inversions within the valley than at the ridge regions.

Meteorological data collected at the site during 1983 can be compared to data for the same period from Grand Junction and to the Grand Junction long-term average for the period 1951-1980. Table 2-22 presents the monthly departures from normal for Grand Junction mean temperature and total precipitation during the current year. The departure of the 1983 mean annual temperature at Grand Junction from the long term average was +2.0 $^{o}$F. The Grand Junction mean annual temperature exceeded the RBOSC Site 1 mean during the current year by 10.5 $^{o}$F. The annual precipitation during the current year at Grand Junction was 15.25 inches, almost double the long-term average. This was still 5.71 inches below the total measured at Site 1 for the year.

Table 2-22. Monthly Departures from the Long-Term Means for the Data Period January-December 1982 for Grand Junction and Comparison with Tract C-a Annual Values.

| Month | Temperature (°F) Long Term Mean | 1982 Mean | Departure from Mean | Precipitation (inches) Long Term Mean | 1982 Mean | Departure from Mean |
|---|---|---|---|---|---|---|
| Grand Junction | | | | | | |
| January | 25.5 | 34.3 | +8.8 | 0.64 | 0.50 | -0.14 |
| February | 33.5 | 40.9 | +7.4 | 0.54 | 0.64 | +0.10 |
| March | 41.9 | 45.9 | +4.0 | 0.75 | 1.59 | +0.84 |
| April | 51.7 | 48.7 | -3.0 | 0.71 | 0.90 | +0.19 |
| May | 62.1 | 58.7 | -3.4 | 0.76 | 1.68 | +0.92 |
| June | 72.3 | 69.8 | -2.5 | 0.44 | 1.54 | +1.10 |
| July | 78.9 | 78.3 | -0.6 | 0.47 | 1.92 | +1.45 |
| August | 75.9 | 80.4 | +4.5 | 0.91 | 0.73 | -0.18 |
| September | 67.1 | 71.4 | +4.3 | 0.70 | 1.11 | +0.41 |
| October | 54.9 | 58.2 | +3.3 | 0.87 | 0.36 | -0.51 |
| November | 39.6 | 42.1 | +2.5 | 0.63 | 2.00 | +1.37 |
| December | 29.5 | 28.1 | -0.4 | 0.55 | 2.28 | +1.73 |
| Annual | 52.7 | 54.7 | +2.0 | 7.97 | 15.25 | 7.28 |
| RBOSC Site 1 | | 44.2 | | | 20.96 | |
| RBSOC departure from Grand Junction | | -10.5 | | | 5.71 | |
| RBOSC Site 1 | 44.1 1/ | | | 15.62 2/ | | |

1/ Based on 8-year data record

2/ Based on 6-year data record

Table 2-22 indicates that Grand Junction data compares rather poorly with onsite data. The mean annual temperature at Grand Junction has been consistently 7-10 $^{o}$F higher than the mean at Tract C-a during the last eight years. In addition, total annual precipitation has been higher at Tract C-a than at Grand Junction in each of the last six years, ranging from 1.7 to 8.3 inches higher. Consequently, Grand Junction data should be used very cautiously in describing the climatology of the region. This climatic difference between Site 1 and Grand Junction can also be seen in the frost-free period (Table 2-11), which has averaged 50 days longer at Grand Junction over the last four years.

This difference is not unexpected, since Grand Junction is located in a valley approximately 2500 feet lower than Site 1. In fact, by using the NACA Standard Atmosphere lapse rate for 40$^{o}$N latitude of 3.57 F/1000 ft (Hess 1959), an estimate can be made of the temperature that would be expected if the Grand Junction station was at the same altitude as Site 1. Using this approximation, the Grand Junction mean annual temperature would be reduced by 8.9$^{o}$F. Thus, the large discrepancy in mean annual temperatures between the site and Grand Junction can be accounted for simply by the altitude differential.

Table 2-23 presents monthly temperature data collected during 1983 from Site 1, three surrounding climatological stations (Rangely, Meeker No. 2, and Little Hills), and Grand Junction. The table shows, as discussed above, that Grand Junction temperature data are not very representative of Rio Blanco County. The mean monthly and annual temperatures at the three climatological stations in the county agree fairly well with the onsite data, especially considering the elevation and topographical differences among the sites. However, a major difference between Site 1 and the other stations is evident in the temperature range (the difference between the maximum and the minimum), which is greater at the climatological stations. This is due primarily to the relative height of the instruments above the ground surface. Climatological stations measure temperature 6 feet above the ground in a standard weather shelter, whereas the Site 1 temperature

Table 2-23. Comparison of Monthly Temperatures (F) in the Vicinity of Tract C-a for the Data Period January-December 1983.

| | Tract C-a Site 1 | | | Little Hills | | | Meeker No. 2 | | | Rangely | | | Grand Junction | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | Avg Max | Avg Min | Mean | Avg Max | Avg Min | Mean | Avg Max | Avg Min | Mean | Avg Max | Avg Min | Mean | Avg Max | Avg Min | Mean |
| January | 34.9 | 24.3 | 29.5 | 37.7 | 7.0 | 22.4 | 41.2 | 13.7 | 27.5 | 35.9 | 8.6 | 22.3 | 43.6 | 24.9 | 34.3 |
| February | 35.1 | 24.1 | 29.3 | 39.8 | 13.1 | 26.5 | 41.9 | 15.6 | 28.8 | 41.6 | 15.8 | 28.7 | 49.5 | 27.5 | 40.9 |
| March | 38.3 | 27.3 | 32.7 | 43.4 | 19.3 | 31.4 | 46.6 | 24.9 | 35.8 | 50.8 | 29.9 | 40.4 | 55.1 | 36.7 | 45.9 |
| April | 41.4 | 27.9 | 34.7 | 49.1 | 20.7 | 34.9 | 51.0 | 24.9 | 38.0 | 55.9 | 30.4 | 43.2 | 60.2 | 37.1 | 48.7 |
| May | 55.0 | 38.8 | 46.9 | 61.0 | 28.3 | 44.7 | 63.4 | 34.0 | 48.7 | 67.5 | 38.6 | 53.1 | 72.7 | 44.7 | 58.7 |
| June | 65.8 | 50.9 | 58.3 | 71.5 | 37.0 | 54.3 | 74.0 | 42.2 | 58.1 | 80.2 | 48.8 | 64.5 | 83.8 | 55.7 | 69.8 |
| July | 75.0 | 57.9 | 66.6 | 82.0 | 46.0 | 64.0 | 83.2 | 50.5 | 66.9 | 91.0 | 54.8 | 72.9 | 91.7 | 64.8 | 78.3 |
| August | 76.8 | 60.4 | 68.7 | 84.3 | 47.4 | 65.9 | 84.9 | 52.6 | 68.8 | | M | | 92.6 | 68.1 | 80.4 |
| September | 69.3 | 51.8 | 60.8 | 78.0 | 34.7 | 56.4 | 78.8 | 42.8 | 60.8 | 84.9 | 44.9 | 64.9 | 85.3 | 57.5 | 71.4 |
| October | 55.2 | 41.9 | 48.4 | 61.6 | 23.1 | 42.4 | 64.5 | 31.7 | 48.1 | 68.2 | 31.5 | 49.9 | 71.0 | 45.3 | 58.2 |
| November | 39.2 | 27.4 | 32.9 | 41.3 | 15.2 | 28.3 | 46.8 | 22.5 | 34.7 | 47.8 | 19.6 | 33.7 | 51.6 | 32.6 | 42.1 |
| December | 27.9 | 15.3 | 21.7 | 29.2 | 6.8 | 18.0 | 32.8 | 12.6 | 45.4 | 28.7 | 5.8 | 17.3 | 36.2 | 20.1 | 28.1 |
| Annual | | | 44.2 | | | 40.8 | | | 46.8 | | | | | | 54.7 |

M = Missing data.

sensor is located at 10 meters (33 ft.). Since temperature changes in the lower layers of the atmosphere result from heat transfer to and from the ground surface, the diurnal temperature range will decrease with height above the ground. Thus, the reduced temperature range at Site 1 relative to the surrounding stations is largely due to the increased height of the temperature sensors at Site 1.

Table 2-24 presents a comparison of precipitation data from Site 1 and from surrounding stations for the current year. Monthly precipitation amounts at all of the stations vary widely due to the complex orographic influences of the region and the intermittent nature of precipitation (particularly during the summer), but annual totals between Site 1 and the climatological stations are reasonably close, ranging between 18 and 21 inches. Grand Junction, with 15 inches of precipitation, had the lowest monthly total of all stations, probably because of its location in a large valley.

Table 2-24. Comparison of Monthly Precipitation (inches) in the Vicinity of Tract C-a for the Data Period January-December 1983.

| Month | Tract C-a Site 1 | Little Hills | Meeker No. 2 | Rangely | Grand Junction |
|---|---|---|---|---|---|
| January | 0.41 | 0.27 | 0.31 | 0.17 | 0.50 |
| February | 0.83 | 1.04 | 1.16 | 0.31 | 0.64 |
| March | 2.10 | 1.65 | 1.27 | 1.53 | 1.59 |
| April | 2.31 | 1.89 | 1.14 | 1.34 | 0.90 |
| May | 4.54 | 3.23 | 1.89 | 2.79 | 1.68 |
| June | 1.13 | 2.48 | 1.69 | 1.03 | 1.54 |
| July | 1.16 | 1.85 | 1.89 | 1.13 | 1.92 |
| August | 0.75 | 1.52 | 1.30 | M | 0.73 |
| September | 0.82 | 0.73 | 0.53 | 0.54 | 1.11 |
| October | 2.26 | 2.18 | 2.03 | 1.15 | 0.36 |
| November | 2.57 | 1.51 | 1.57 | 1.44 | 2.00 |
| December | 2.08 | 1.83 | 2.85 | 1.16 | 2.28 |
| Annual | 20.96 | 20.18 | 17.63 | M | 15.25 |

M = Missing Data

## 2.4 QUALITY ASSURANCE AND DATA RECOVERY

The data upon which this report is based, with the exception of the visibility, precipitation and total suspended particulate data, were collected by an automatic data acquisition system located on Tract C-a. The data are recorded on magnetic tape, paper printouts and analog strip chart recorders. A comprehensive quality assurance program has been maintained to ensure the reliability and accuracy of the data. This program includes documentation by the site technician of all calibrations and system malfunctions, weekly zero and span calibrations of the air quality instrumentation, utilization of control charts onsite to detect problems in the weekly span calibrations, quarterly calibrations of the air quality instrumentation by both the RBOSC technical staff and an independent auditing team, semiannual calibrations of the meteorological instrumentation, and review of the analog and digital data by qualified analysts.

The air quality instruments are calibrated with reference gases traceable to National Bureau of Standards (NBS) standards. The carbon monoxide, sulfur dioxide, hydrogen sulfide, and nitrogen oxide analyzers were calibrated using known concentrations of test gases which had been certified by the vendor. The ozone analyzer is calibrated using a U.V. photometer.

Each instrument was tested at least once a week by inserting a zero pollutant concentration and at least one upscale concentration. These tests provided data on instrument drift and ensured that the instrument would respond to a detectable level of pollutant concentration in the ambient air.

The quarterly field calibrations were used to determine the accuracy of the instruments. Independent quarterly audits by a contractor (Northrop, Inc.) were used to check the field calibrations.

The air quality data include many values representing hours when the concentration of some pollutants fell below the reliable threshold of detection of the instrument (based on the manufacturer's specifications). When this occurred, a number equal to one-half the threshold value was substituted for the data point. This procedure is adopted from the EPA Quality Assurance Handbook, Air Pollution Measurement, Vol. 1. This applied to sulfur dioxide, hydrogen sulfide, nitrogen oxides, and carbon monoxide data acquired through much of the data period.

The meteorological system is calibrated on a semiannual basis. This includes routine replacement of all wind speed and wind direction sensors. No correction factors were required to adjust the data.

Data recoveries for all meteorological and air quality parameters collected by the onsite data acquisition system are presented in Tables 2-25 and 2-26. Despite a lightning strike in May, 1983, the data recovery of each meteorological or air quality parameter was at least 89 percent, with the exception of the solar radiation. The data loss for this parameter was primarily due to another lightning strike at Site 1 in late 1982. The instrument was severely damaged and had to be returned to the manufacturer for repair and recalibration.

Table 2-25. Annual Data Recovery (%) of Air Quality Parameters Monitored at Tract C-a for the Period January-December 1983.

| Parameter | Data Recovery (%) |
|---|---|
| Site 1 | |
| $SO_2$ | 96 |
| $H_2S$ | 91 |
| NO | 89 |
| $NO_2$ | 89 |
| $O_3$ | 95 |
| CO | 99 |

Table 2-26. Annual Data Recovery (%) of Meteorological Parameters Monitored at Tract C-a for the Period January-December 1983.

| Parameter | Data Recovery (%) |
|---|---|
| Site 1 | |
| 10 m wind speed | 95 |
| 10 m wind direction | 94 |
| 60 m wind speed | 94 |
| 60 m wind direction | 93 |
| 10 m temperature | 97 |
| 60 m temperature | 94 |
| Delta T 60-10 m | 94 |
| Solar radiation | 75 |

## 2.5 VISIBILITY

Documentation of visibility in the Piceance Creek Basin is a cooperative study conducted by RBOSC and the Cathedral Bluffs Shale Oil Company. Analysis of the 1983 visibility data has not yet been completed and will be provided in the next monitoring report.

## 2.6 SUMMARY

Both air quality and meteorological data were collected at sites near Tract C-a during 1983. No violations of any National Ambient Air Quality Standards (NAAQS) were detected. Considering the very low activity level on and around the tract, this result is not surprising. With the exception of ozone and total suspended particulates (TSP), concentrations of all air quality parameters were found to be near or below the threshold of detection of the state-of-the-art instruments used in the monitoring program.

The range of ozone concentrations recorded during 1983 was 0.015 to 0.073 ppm. This range of concentrations is very similar to that found in previous years, and appeared to be uninfluenced by the decrease in site activity. This lends support to the hypothesis advanced in earlier reports that the source of the ozone concentrations is located elsewhere (e.g., ozone is brought in by long range transport or stratospheric injection).

Although peak summertime concentrations of TSP in 1983 were similar to concentrations in 1982 and 1981 (approximately one-half of the secondary NAAQS for TSP), the annual geometric mean concentrations have dropped substantially. This drop in TSP concentrations has been greatest at Site 3, which was probably impacted in earlier years by activity on and around the tract. At present, both TSP sites appear to be measuring primarily background concentrations, with little impact due to localized activity. The correlation of the two TSP data sets on an annual basis was high at 0.83.

The meteorological data from 1983 showed that the year was near the average temperature of the previous seven years, but much wetter. The annual temperature range of 52 $^{o}$C is typical of a continental climate. Precipitation at the tract totalled approximately 21 inches during 1983, which is the highest total recorded during the period of record. Several of the climatological stations in the area also recorded the highest precipitation in several years. The six-year mean precipitation at Site 1 is approximately 16 inches. The most common wind direction was south-southwest, which has been the case for several years. Average wind speed at the 10-m level was 6.6 mph.

## LITERATURE CITED


Colorado Department of Health, 1983. Ambient Air Monitoring Requirements for the Air Pollution Control Division of the Colorado Department of Health.

Hess, Seymour L. 1959. Introduction to theoretical meteorology, Holt, Rinehart and Winston, NY.

Rio Blanco Oil Shale Project. 1977. Final environmental baseline report for Tract C-a and vicinity. Gulf Oil Corp. and Standard Oil Co. (Indiana).

Rio Blanco Oil Shale Company. 1978. Modular development phase monitoring report 2, December 1977 - May 1978. Gulf Oil Corp. and Standard Oil Co. (Indiana).

_____. 1979a. Modular development phase monitoring report 3, December 1977 - November 1978. Gulf Oil Corp. and Standard Oil Co. (Indiana).

_____. 1979b. Modular development phase monitoring report 4, December 1978 - May 1979. Gulf Oil Corp. and Standard Oil Co. (Indiana).

_____. 1980. Modular development phase monitoring report 5, December 1978 - November 1979. Gulf Oil Corp. and Standard Oil Co. (Indiana).

_____. 1981. Modular development phase monitoring report 7, December 1979 - November 1980. Gulf Oil Corp. and Standard Oil Co. (Indiana).

_____. 1982. Modular development phase monitoring report 9, December 1980 - December 1981. Gulf Oil Corp. and Standard Oil Co. (Indiana).

_____. 1983. Modular development phase monitoring report 11, September-November 1982. Gulf Oil Corp. and Standard Oil Co. (Indiana).

# SECTION 3
# TERRESTRIAL STUDIES

## 3.0 INTRODUCTION

The objectives of the Terrestrial Studies portion of the MDP Environmental Monitoring Program are to conduct monitoring required by the environmental stipulations in the Tract C-a lease, and to detect and evaluate (in terms of development-related impact) changes in the vegetative or faunal components of the terrestrial ecosystems on or near Tract C-a.

The sampling program associated with the Terrestrial Studies is geared to the seasonal cycles of the ecosystems involved. During the 1983 reporting year, analyses for vegetation mapping and stress, and surveys of mule deer density and mule deer road kill were conducted. The results of these monitoring activities are reported in this section of MDP 13.

The design of the Terrestrial Studies program is based on current knowledge of Tract C-a ecosystems and RBOSC project development plans. As the development of Tract C-a is a pioneering effort, such development plans are subject to frequent modification. The basic knowledge of Tract C-a ecosystems is also increasing. These factors result in frequent changes to the Terrestrial Studies portion as well as other components of the MDP Environmental Monitoring Program.

Terrestrial data presented in this report were collected according to the methods described in the Modular Development Phase Environmental Monitoring Program Scope of Work, Revision 7.0 (RBOSC 1983b). All data were verified in compliance with RBOSC quality control procedures, which included supervisory verification of field data sheets, laboratory analysis, and data management processes. Documentation supporting these quality control procedures appears in the RBOSC Quality Assurance files.

## 3.1 VEGETATION

### A. Vegetation Mapping and Stress

#### 1. Objectives

Construction and operation of Tract C-a facilities may affect the local distribution and/or condition of vegetation types. The vegetation studies are designed to monitor the distribution of vegetation on Tract C-a and adjacent areas to determine large-scale changes resulting from MDP development, to identify stress conditions, and to document changes over time in the plant communities.

#### 2. Methods

Plant community stress conditions are assessed using color infrared (CIR) aerial photographs taken of the same areas over the period of several years. Healthy plants which are not under moisture stress and/or stress from airborne pollutants appear in red on the CIR photographs. Variations in red tones, which identify photosynthetic activity, on the CIR photographs serve to delineate changes in plant communities under stress. In instances where stress is severe and/or prolonged, the absence of red tones may indicate plant death. In the case of MDP development on Tract C-a, stress conditions could potentially be related to emissions from MIS retorts, drawdown of the upper aquifer as a result of mine dewatering, and/or surface discharge of waters.

Stress conditions over time are identified by comparing photographs taken on successive years. In order to minimize variations among years that might be related to seasonal conditions, aerial photography is flown as close as possible to the same time of the year. Furthermore, care is taken during film processing and printing to ensure that color balance is the same for each photographic series as well as between years.

Photographic coverage of Tract C-a and vicinity has varied among years but at least two years of data have been obtained for each major drainage on, or adjacent to, Tract C-a. Table 3-1 lists the areas covered by year during MDP monitoring. Additionally, photographs taken during 1974 were used as an early baseline to identify areas where soil moisture status was sufficient to support more mesic vegetation than typically encountered in the upland areas of the Piceance Basin surrounding Tract C-a. Although the CIR portion of RBOSC's Environmental Monitoring Program was discontinued after the 1981 season, analyses of 1981 data, as well as those for 1979 and 1980 covering areas other than Tract C-a per se, were deferred until 1983/1984 for manpower and scheduling reasons.

Although several different firms were utilized to take aerial photographs, a 9 inch x 9 inch negative format was used during all years. Blanket coverage, utilizing north-south flight lines was employed during 1974 and 1979. The 1974 photography, flown by Intra Search Inc. of Denver (scale 1" = 1,000') covered portions of the Piceance Basin well beyond the area of interest in this study. Only those frames including Tract C-a or the drainage in question were used in this study. During 1980 and 1981 flight lines centered on the desired drainages were employed. The scale of photographs taken during 1979-1981 was approximately 1" = 500'. This scale provided a level of detail sufficient to identify individual trees and shrubs in many instances. The 1979 and 1980 photography was taken by Air Photo Surveys and Global Engineering, Inc. of Grand Junction while the 1981 photographs were obtained by Scharf and Associates, Denver, Colorado.

Because of the short duration of the in-situ retort burns and because mine dewatering/reinjection activities had the potential for more readily identifiable impacts as evidenced via CIR photography, the focus of between year comparisons of CIR photographs has been the major drainages on and adjacent to Tract C-a. Areas of moderate to high soil moisture, as inferred from red tones on CIR photographs, were first identified and delineated within these drainages using the 1974 photographs. Qualitative changes in apparent moisture status with surface soils, as based on vegetation within these

Table 3-1. Areas Covered by CIR Photography on and Adjacent to Tract C-a During MDP Monitoring 1974-1981.

| Area of Coverage | Year | | | | |
|---|---|---|---|---|---|
| | 1974 | 1978[1/] | 1979 | 1980 | 1981 |
| Stake Springs Draw | X | _ | X | X | _ |
| Box Elder Gulch | X | _ | X | X | _ |
| Corral Gulch | X | _ | X | X | X |
| Big Duck Creek | X | _ | X | X | X |
| Yellow Creek | X | _ | X[2/] | X | X |

1/ Quality of film and/or difficulties with processing rendered 1978 CIR photography unusable.

2/ From 84 Ranch to the confluence with Duck Creek.

drainages, were then ascertained using variations in red tones on the CIR photographs and plotted relative to the predevelopment (1974) conditions. Where appropriate, attempts have been made to relate changes to Tract C-a activities and climate-related variations.

## 3. Results

Assessments of CIR photographs reported herein include the documentation of moisture status within Stake Springs Draw from Range 100 West to Yellow Creek, Corral Gulch from the western Tract C-a boundary to the confluence with Yellow Creek, Big Duck Creek from Range 100 West to Yellow Creek, and Yellow Creek from 84 Ranch to the White River (Figure 3-1). In most instances comparisons are based on data from at least three years, as specified on Table 3-1. Data from 1979 and 1980 for Corral Gulch and Box Elder Gulch on Tract C-a were reported in MDP Environmental Monitoring Reports 5 and 7 (RBOSC 1980, 1981), and are not duplicated here. Photographs are on file at RBOSC's Denver office.

a. Stake Springs Draw - The majority of the valley bottom of Stake Springs Draw from T2S, R99W, Section 30 to the confluence with Corral Gulch and Yellow Creek (Figure 3-1) showed varying degrees of red (moist areas) on 1974 photographs. The areas of greatest moisture were noted in the vicinity of Stake Springs, Sections 14 and 15. Eight areas of change were identified during subsequent years, as noted on Figures 3-2 and 3-3.

Three of the eight sites were located in Sections 14 and 15, in close proximity to Stake Springs. The two locations in Section 15 supported vegetation which indicated probable increased moisture in 1980 relative to 1979. The third site (Section 14) showed increases in 1979 over 1974, as well as in 1980 over that evidenced in 1979. It is interesting to note that a one-mile segment of Stake Spring Draw adjacent to the spring is one of only two portions of the study area within Stake Springs Draw where surface flow is evident throughout the year. Variations in this flow may well influence moisture status as interpreted from the CIR photographs.

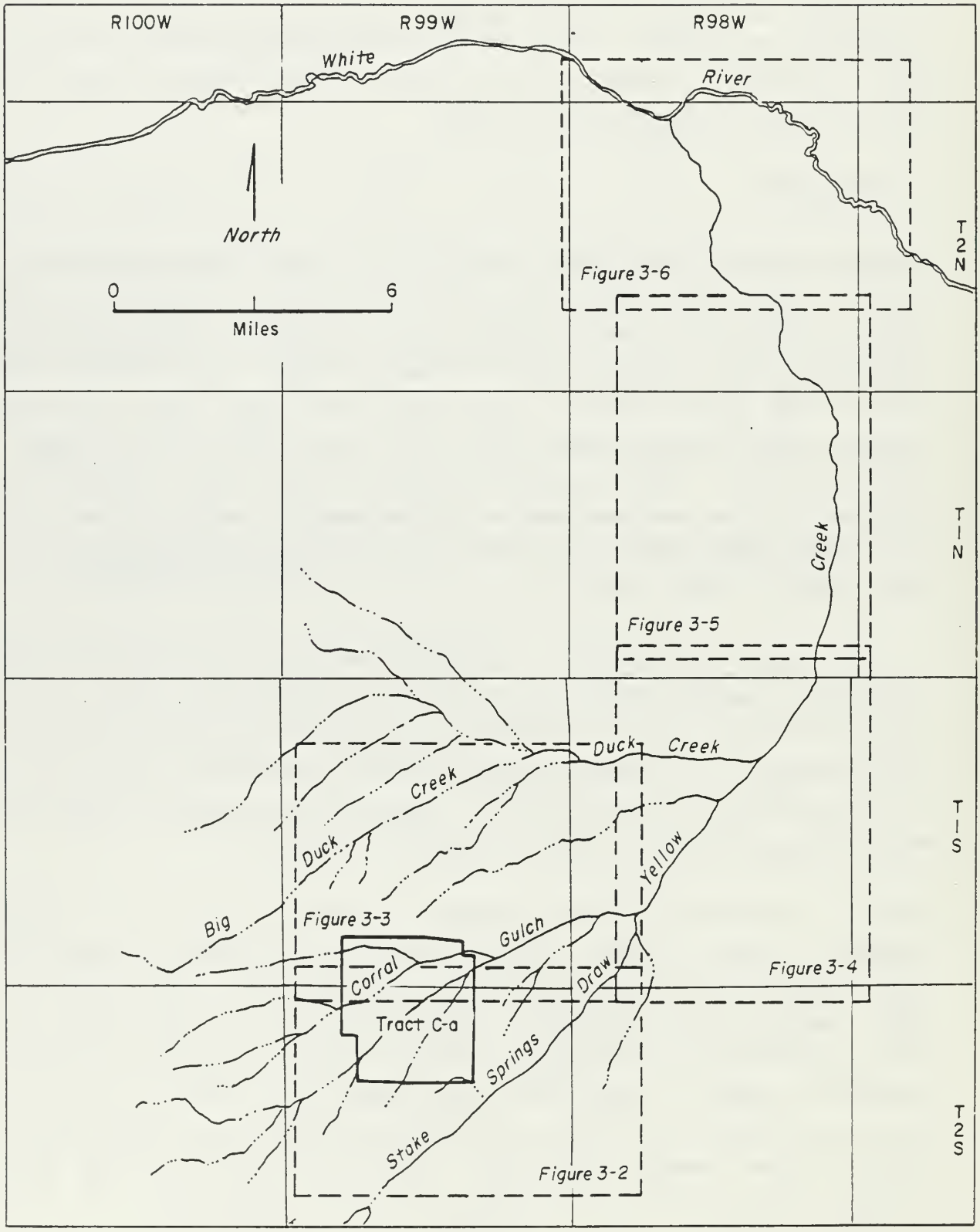



Figure 3-1. Index to figures which show areas of change in "Moisture Regime" on CIR photography.

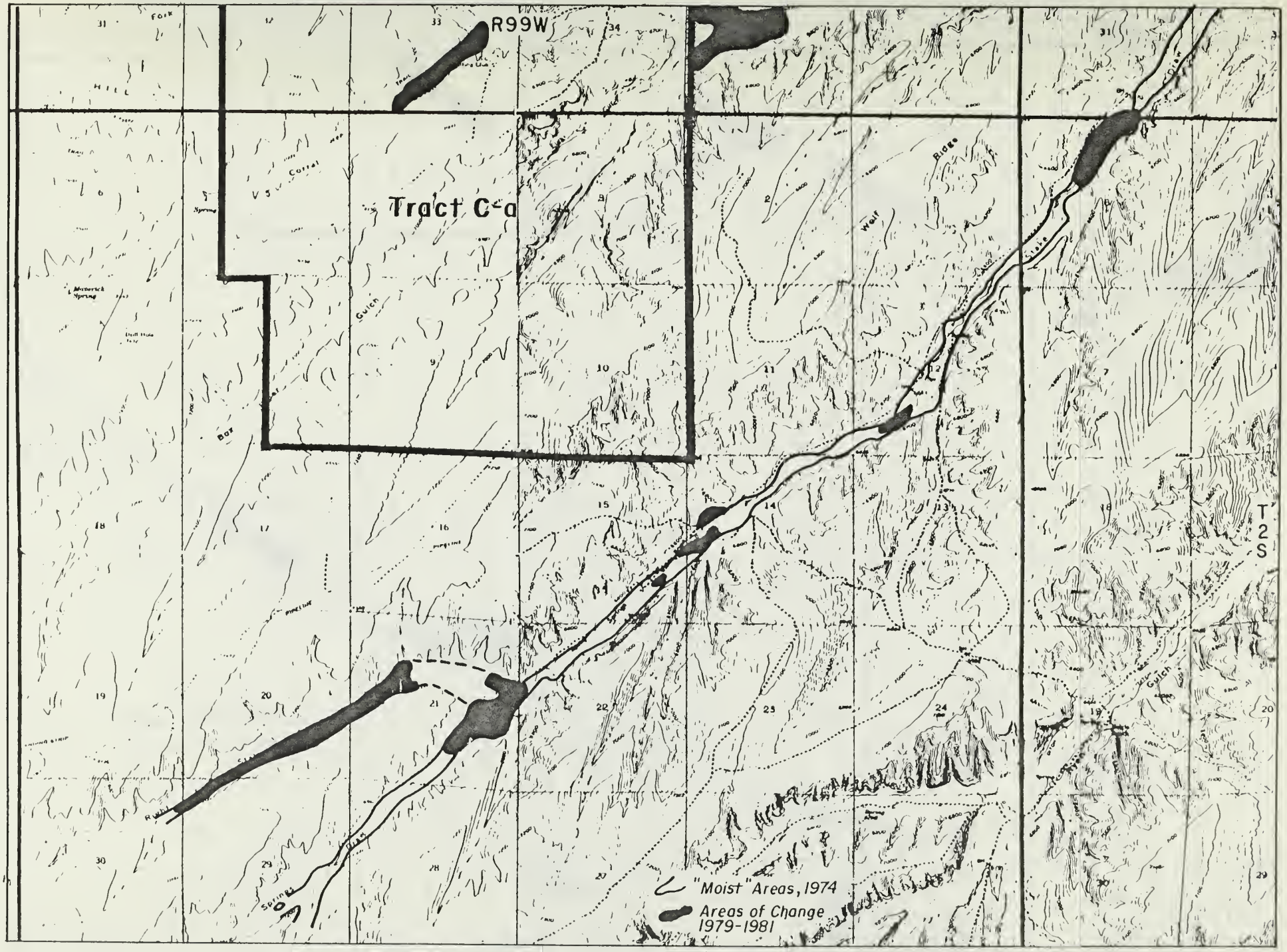



Figure 3-2. Areas of change in "Moisture Regime" as noted on CIR photography, 1974-1981.

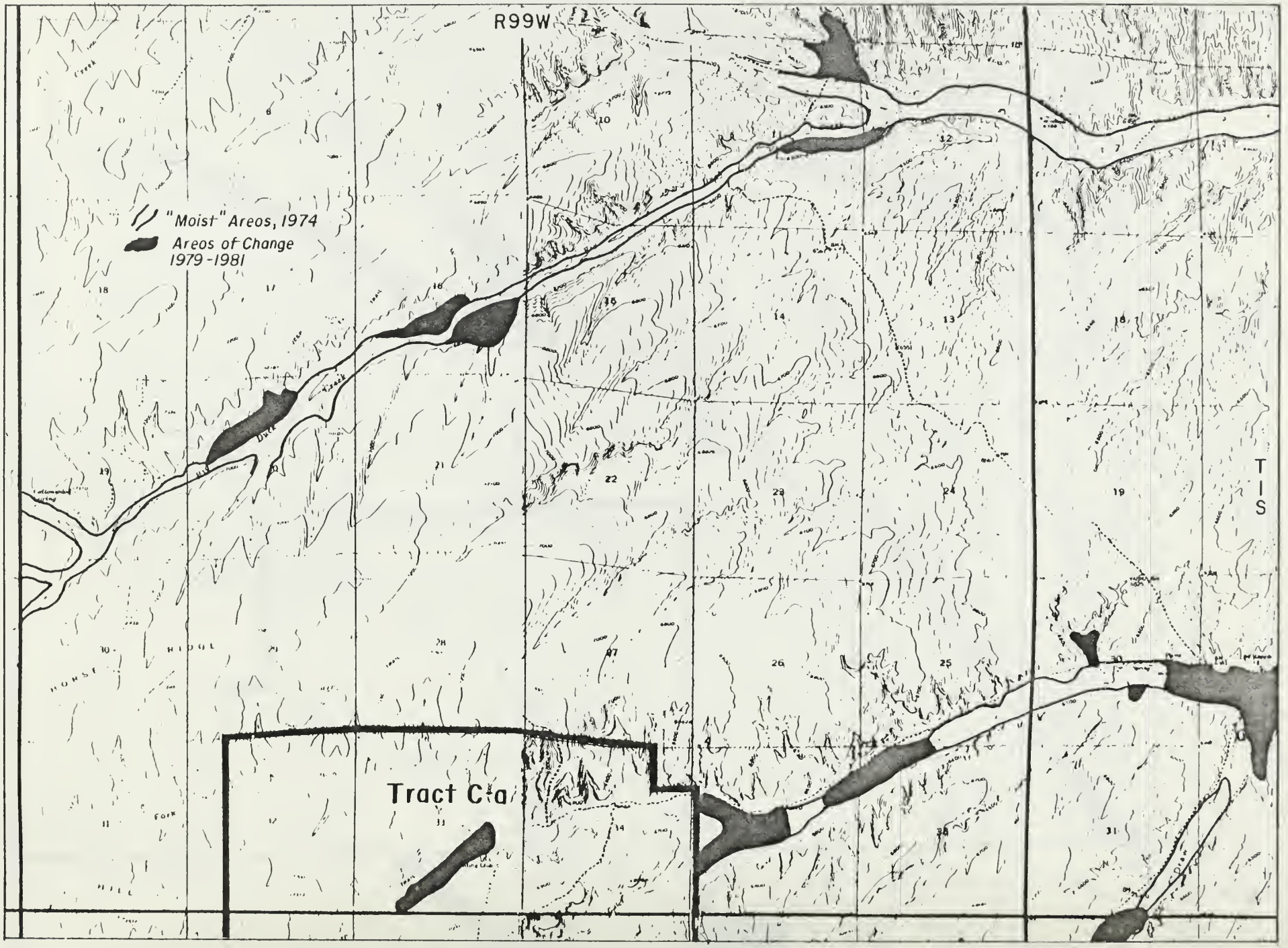



Figure 3-3. Areas of change in "Moisture Regime" as noted on CIR photography, 1974-1981.

Upstream from Stake Springs, at the confluence of the Left and Right Forks of Stake Springs Draw, another area of increase in 1979 relative to 1974 was noted in Section 21. The only decrease in moisture (1980 vs. 1974) found in Stake Springs Draw was located along the valley bottom on the Right Fork (Sections 20 and 21).

Three areas of increased moisture downstream from Stake Springs were also noted. In Section 12 a relatively small area exhibited an apparent increase in 1980 vs. 1979. Increases were also noted in Section 6, T2S, R98W, and in Section 29, T1S, R98W (see Figure 3-4). In the case of the former site (Section 12), the area in question is immediately upstream from the second area of surface flow occurring within Stake Springs Draw. Historically, surface flows in this general area have been used for irrigation and/or livestock use.

Based on these observations it is not likely that Tract C-a operations have influenced moisture status in Stake Springs Draw. Although dewatering activities resulted in a drawdown of the upper aquifer which reached to the vicinity of Stake Springs, changes in moisture status registered around Stake Springs were increases in both 1979 and 1980. This corresponds to the same time when the drawdown was at the greatest extent. Cone of depression illustrations for the 1979-1980 period are available in MDP monitoring reports (RBSOC 1980, 1981). It is remotely possible that reinjection at wells on Wolf Ridge may have been related to these moisture increases. The fault systems in the vicinity trend toward the southeast from Wolf Ridge and could provide an avenue for moisture migration toward Stake Springs.

b. Box Elder Gulch - Changes during 1974, 1979 and 1980 were reported in previous reports. Box Elder Gulch was not included within areas flown during 1981.

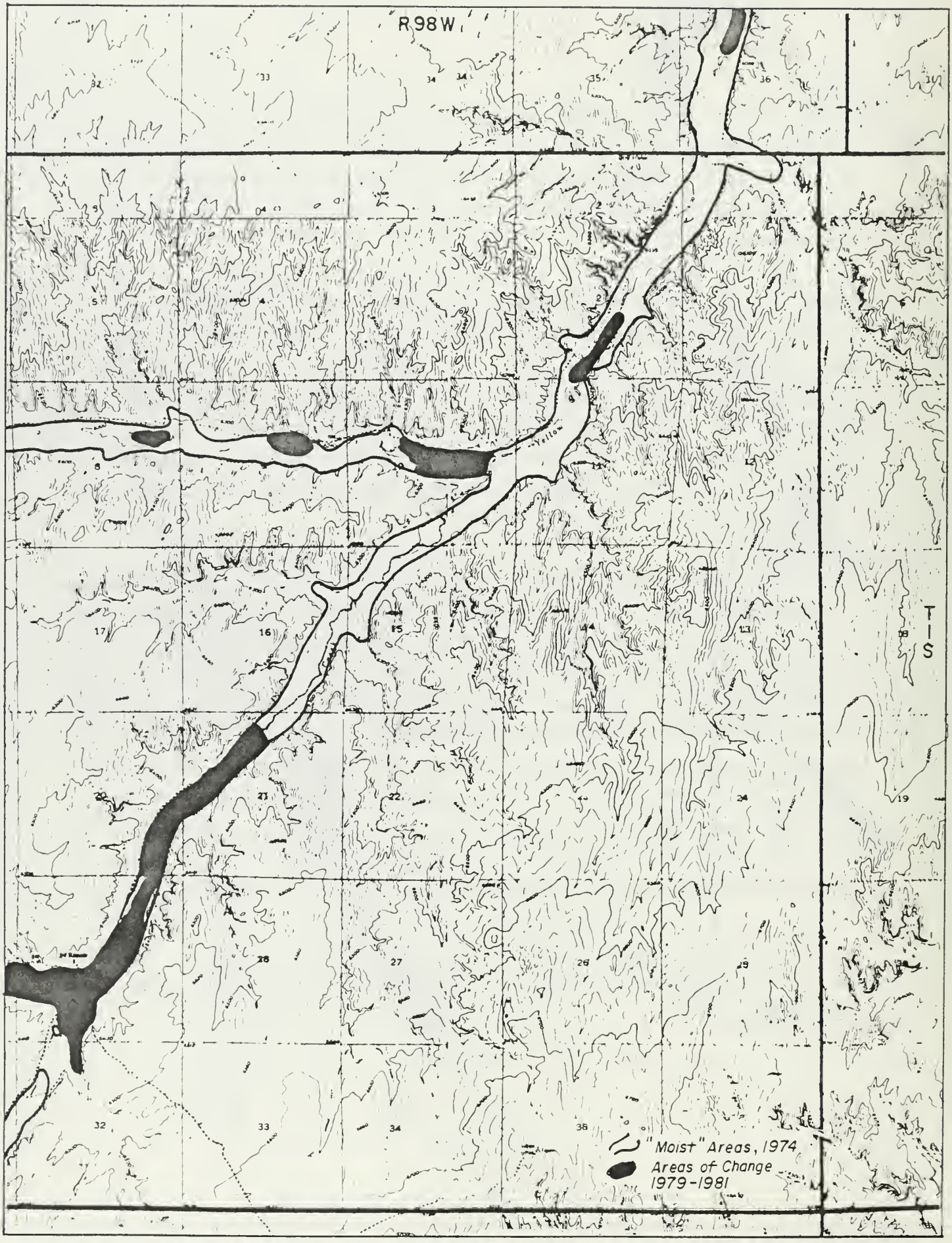



Figure 3-4. Areas of change in "Moisture Regime" as noted on CIR photography, 1974-1981.

c. Corral Gulch - Aside from the variations noted in MDP Environmental Monitoring Reports 5 and 7 (RBOSC 1980, 1981), only one area of change was noted during 1981 on Tract C-a (Figure 3-3). This area is adjacent to the surface discharge point where mine water is released into Corral Gulch (Section 33, T1S, R99W). In this instance, there appeared to be a slight decrease in moisture within the alluvium during 1981 as compared to 1980. Because this area of decrease extends as much upgradient from the discharge point as it does downstream, the change in moisture status seems to be the result of natural variations rather than tract operations.

There were three primary areas of change between the eastern Tract C-a boundary and the confluence with Yellow Creek. Areas of change noted on Figure 3-3 illustrate apparent increased moisture in 1979 vs. 1974 in Sections 35 and 36, T1S, R99W, and in Sections 29 and 30, T1S, R98W. These areas of change continued to be evident during 1980 and 1981 as well. Changes immediately east of Tract C-a have been discussed in MDP 5, and may be related to a combination of surface discharge of mine water as well as reinjection. Both activities could potentially increase moisture availability in the alluvium. Although photographs are not available for 1983, on-site observations of surface flows in Corral Gulch during 1983 confirm the supposition of widespreading flows occurring in Sections 35 and 36, as put forth in MDP 5. Naturally occurring flows such as those of 1983 appear to be the primary contributors to the status of vegetation in this particular portion of Corral Gulch.

Although several variations among years were noted in gullies tributary to Corral Gulch (Sections 29 and 30, T1S, R98W), the primary change in this general area appeared to be related to irrigation. Photographs document limited irrigation in 1974 followed by increased irrigation activity during 1979, 1980 and 1981. Reinjection and/or discharge of water on Tract C-a may have allowed for at least a portion of the increase in irrigation activity.

d. Big Duck Creek - Seven areas of change were noted between Cottonwood Springs and the confluence of Duck Creek with Yellow Creek (Figures 3-3 and 3-4). In Section 20, T1S, R99W there appeared to be an increase in 1979 relative to 1974, followed by a decrease in 1980 and 1981. This location corresponds to the general vicinity where surface flows occur; however, the specific area in question is somewhat removed from the valley bottom and may not be influenced to any great degree by this flow.

Near the confluence of Big and Little Duck Creeks, Sections 2, 11, and 12, T1S, R99W, two additional areas of apparent change were identified. The area in Big Duck Creek (primarily within Section 12) exhibited an increase in moisture during 1979 vs. 1974. This increase continued to be evident in both 1980 and 1981. The second site, which is adjacent to Little Duck Creek but primarily within Trail Canyon (Sections 11 and 2) exhibited an apparent increase in moisture during 1980 and 1981 relative to 1974.

The remaining three areas of change in the Duck Creek drainage were identified in Sections 8, 9, and 10, T1S, R98W (Figure 3-4). All three locations are in the vicinity where surface flows occur. In each instance, apparent increases were noted in 1979 vs. 1974. Furthermore, the areas in Sections 9 and 10 appear to have been subjected to brush modifications, perhaps as a means of increasing forage for livestock. A number of instances of brush fires have also been reported in this general area and these fires may have altered the character of vegetation as noted on the photographs.

Although the cone of depression in the upper aquifer resultant from mine dewatering efforts reached Big Duck Creek in the vicinity of Sections 16 and 20, T1S, R99W (Figure 3-3) (see also RBSOC 1980 and 1981 for cone of depression illustrations), changes in the status of moisture in the aforementioned sections have been increases, as opposed to reductions which would be expected as a result of the lowering of the aquifer. Therefore, it seems that tract-related activities have not influenced the moisture status within the alluvium in Duck Creek to any measurable extent.

e. Yellow Creek - Of the four areas of change noted on Yellow Creek (Figures 3-4, 3-5, 3-6), the most noteworthy site extends several miles down gradient from 84 Ranch (Sections 20, 21, 29, T1S, R98W) (Figure 3-4). This portion of the drainage frequently supports surface flow and is amenable to irrigation, as witnessed by numerous irrigation ditches. During 1974 little apparent irrigation occurred; however, by 1979, 1980 and 1981 the photographs illustrate that the area was being irrigated fairly regularly. With the increased natural flows experienced during 1983 it is likely that the alluvium in this area, along with that of much of the valley bottoms throughout the Yellow Creek Drainage, was well saturated.

An apparent increase in moisture during 1980 relative to 1974 was evident in Section 2, T1S, R98W and was evident during 1981 as well (Figure 3-4). This site is approximately one half mile upgradient from the point where surface flow emerges from the alluvium. Another area of apparent increased moisture occurs just below the point where this surface flow again returns to the alluvium (Section 36, T1N, R98W). At this second location increased moisture was noted in 1979 photographs relative to those taken in 1974, and the increase remained evident during 1980 and 1981. Because of their proximity to surficial flow, moisture at both of these sites may be influenced by whatever structural characteristics control movement of groundwaters into or out of the alluvium.

The only other area of change noted within Yellow Creek occurred in Section 22, T2N, R98W, near Stinking Spring (Figure 3-6). At this site an increase was noted for 1979 vs. 1974, and continued to be evident in 1980 and 1981 as well. Because of its proximity to the spring, one might assume that variations at this location are related in some way to Stinking Spring.

Aside from supplying water to the drainage system which in turn may facilitate increased, or more regular, irrigation of bottomlands in Corral Gulch and Yellow Creek, none of the changes identified from these analyses seems to be related to tract-related activities. Although variations in moisture

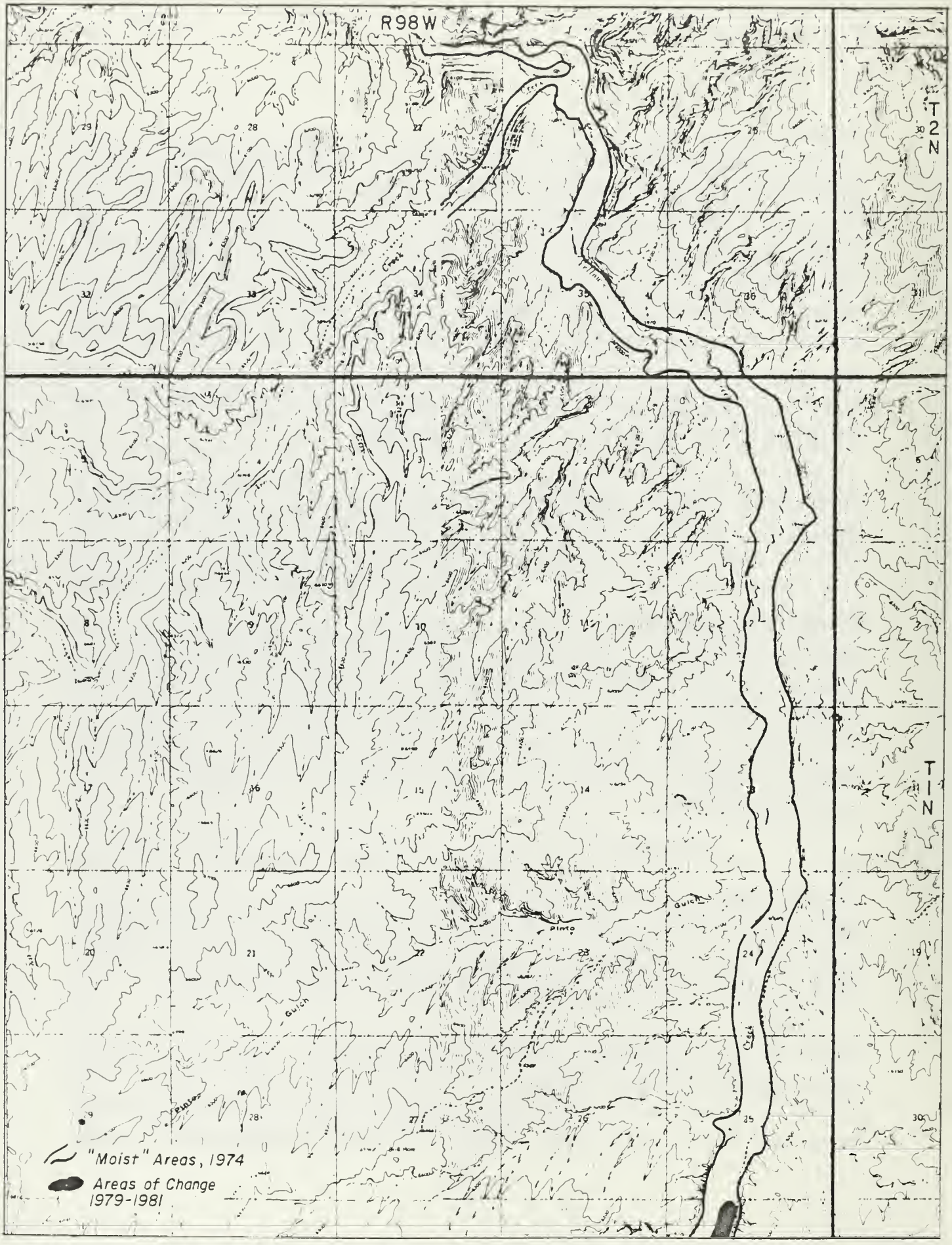



Figure 3-5. Areas of change in "Moisture Regime" as noted on CIR photography, 1974-1981.

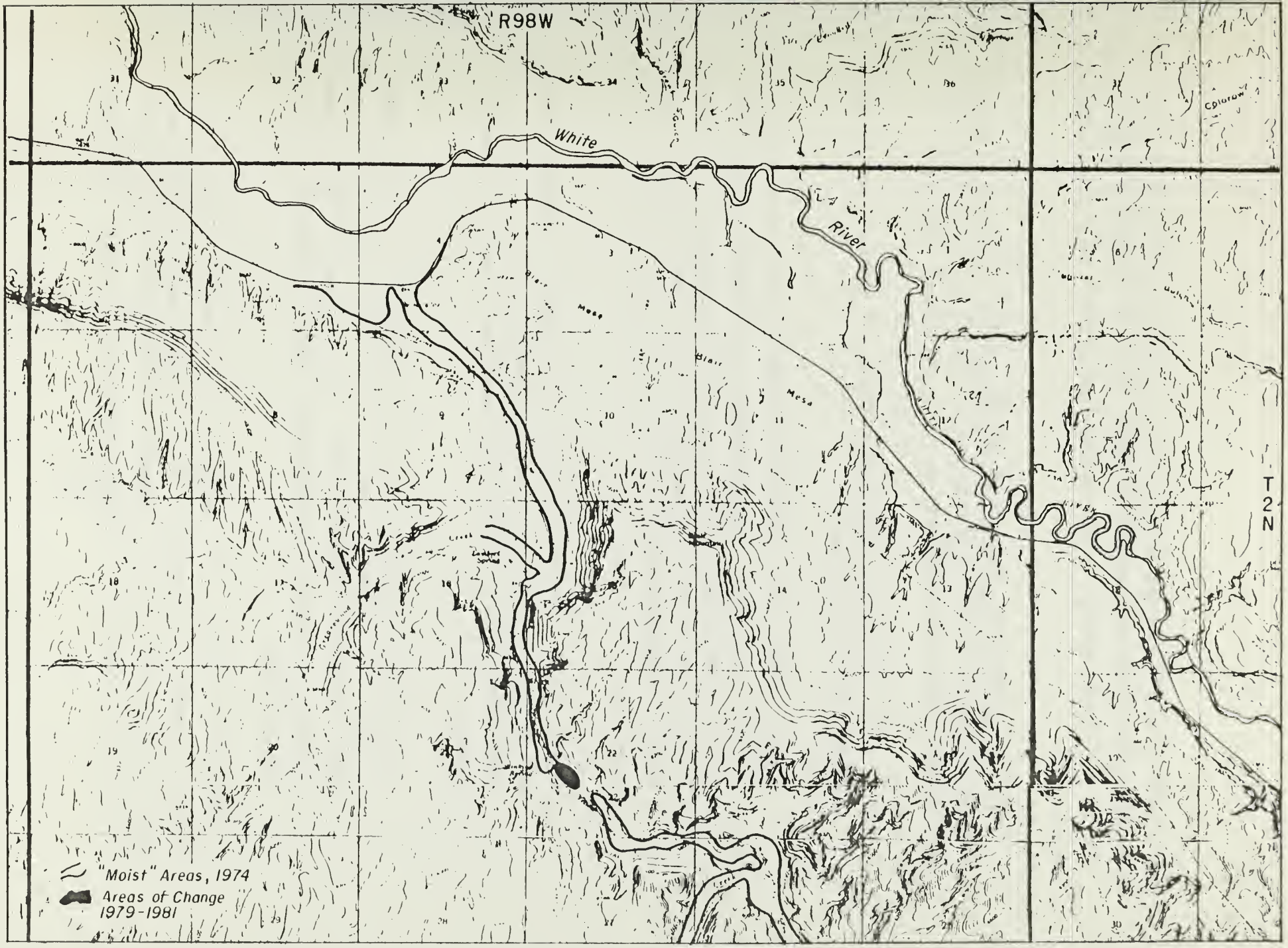



Figure 3-6. Areas of change in "Moisture Regime" as noted on CIR photography, 1974-1981.

status have been documented on CIR photographs taken over several years, any increased flow within the alluvium which may have been related to Tract C-a has no doubt been masked by the abundance of natural flow which occurred during 1983.

f. Recommendations for Use of CIR Photography - Although CIR aerial photographs provide an excellent overview of Tract C-a and vicinity, their use in quantifying potential impacts is limited by several factors:

- o It is difficult to achieve uniformity of exposure and/or color balance from year to year.

- o Changes between years are largely subjective, due to the perception of color variations. Quantification via computer scanning might eliminate the subjectivity but would be very expensive at this scale (1 inch = 500 feet) of photography. In any case, potential variation in exposure and/or color balance among years would still be a concern.

- o Because of the natural variation in the amount of moisture within the alluvium of the drainages in question, it is difficult to distinguish between natural and man-induced changes in moisture status.

- o The degree of definition on the CIR photographs, or lack thereof, resultant from upland vegetation is such that impacts related to emissions might be overlooked until the vegetation had all but died. Therefore, the use of CIR photographs might be limited to moisture related impacts.

If sufficiently sensitive CIR photographs at a smaller scale could be analyzed via computer, the technique may be of some use in assessing early impacts from both water and stack emissions. Work by Werner Frei et al. has been directed at this sort of effort; however, at this point the results

seem questionable and the use of the technique should be contingent upon further refinement before being considered as a monitoring tool for Tract C-a.

## 3.2 FAUNA

### A. Mule Deer Density

#### 1. Objectives

Mule deer (Odocoileus hemionus) is the most important game species in Colorado in terms of recreational use and money expended by hunters. The Piceance Creek Basin is the wintering area of one of the largest migratory mule deer herds in the U.S. Tract C-a is within the Piceance Creek Basin which, for the most part, corresponds to the Colorado Division of Wildlife's Game Management Unit 22.

Moderate to high numbers of mule deer occur on and in the vicinity of Tract C-a during the winter and migration periods. Deer are uncommon around Tract C-a during the summer.

Consideration of the possible effects of Tract C-a development on mule deer is an integral part of RBOSC's Fish and Wildlife Management Plan. The objectives of RBOSC's mule deer monitoring program are to obtain indices of mule deer density in a 9 x 9 mile (81 sq. mi) study area centered on Tract C-a (the tract and a 3-mile buffer zone), to compare indices of mule deer density from the study area with those from Game Management Unit 22 and, if possible, to compare differences in mule deer densities within various portions of the study area.

#### 2. Methods

Mule deer densities can be estimated from pellet group density data because mule deer daily defecation rates are reasonably uniform (Neff 1968). The number of pellet groups per unit area, days of use by deer, and deer per unit area in the RBOSC study area are determined as described by Overton (1971). The methods followed for collection and analysis of these data are described in RBOSC MDP Monitoring Report 1 (RBOSC 1978).

Until 1983 when studies were conducted only during June, mule deer pellet groups have been counted every spring and fall since 1978. The RBOSC mule deer study area is composed of nine blocks, each 9 square miles in extent. Within each block are seven quarter-section sampling units, which were randomly selected during the design of the study. Pellet counts are made on 20 permanent plots within each of these 63 quarter-section sampling units, for a total of 1260 plots.

In an effort to determine habitat qualities important to deer, comparisons were made of pellet group counts as related to various descriptors recorded for each of the 1260 plots in the study area. These descriptors are elevation, slope, aspect and vegetation type. The descriptors are further categorized into components. For example: the aspect descriptor is broken down into eight compass directions plus flat (faces straight up), and the vegetation type descriptor is composed of 6 different vegetation types. The number of plots in each of the descriptor components is fixed. It is assumed that deer preference for any component can be estimated by pellet group occurrence. If deer did not prefer one component over another, the proportion of total pellet groups for the study area in one component should equal the proportion of the total number of plots in that component. For example, if 25% of all plots were in the vegetation type component mixed-brush and deer did not prefer mixed-brush over or under any other vegetation type component, we would expect that, by random chance, 25% of all pellet groups would fall on those plots.

Relative use factors for descriptor components are derived by dividing the percent of the plots in a given component into the percent of the total annual pellet groups in that component. Because the percent of plots in a given component is fixed, the higher the percent of pellet groups in a component, the higher the relative use factor.

## 3. Results and Discussion

Mule deer winter density estimates for the MDP monitoring period, based on pellet group counts, are presented in Table 3-2. Pellet group counts for all plots during the 1982-83 winter are presented in their entirety in Appendix 3-2.1. The mule deer density during the winter of 1982-83 ranged from 10 to 76 deer per square mile (deer/$mi^2$) among the 9 blocks comprising the study area, with an average density for the entire study area of 38 deer/$mi^2$. Over the 6 years of data collection, the average number of deer/$mi^2$ for the study area during the winter has been 37. The highest average deer density was found in the winter of 1977-78 (51 deer/$mi^2$), while the lowest average density (28 deer/$mi^2$) was recorded during the winters of 1979-80 and 1980-81. The severe winter die-off experienced in 1978-79 is reflected in the deer density of 1979-80. The low deer density in the study area in 1980-81 is probably a result of the mild winter which allowed the deer to remain at elevations higher than the majority of the study area. In general, the deer herd appears to be increasing from the low level of 1979-80.

Block 5, which includes Tract C-a, has the highest average deer/$mi^2$ over the 6 years of study. This high density is probably a result of the habitat diversity in this Block. See MDP Monitoring Report 11 for a discussion on the influence of habitat diversity on winter deer density (RBOSC 1983a).

Relative mule deer use factors for the plot descriptor elevation are presented in Table 3-3. Over the six winters sampled (1978-1983), highest proportions of pellet groups were found in the elevation range between 7,000 and 8,000 feet. This elevation range probably represents that zone where adequate moisture exists for good forage growth but where snow depths are shallow enough to permit deer activity in the winter. Relative use factors in the severe winter of 1979 were higher in the lower elevation components where snow depths were shallower. During the mild winter of 1981, deer apparently spent more time at the higher elevations where more favorable forage was available due to low snow depth. The relative use factors for

Table 3-2. Calculated Number of Mule Deer Per Square of Winter Range on Nine Sample Blocks Comprising the Wildlife Monitoring Program near RBOSC Tract C-a.

| Block Number | Winter Distribution Deer Per Square Mile 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | Avg. |
|---|---|---|---|---|---|---|---|
| 1 | 63.10 | 62.20 | 32.45 | 55.89 | 52.28 | 47.78 | 52.28 |
| 2 | 46.87 | 72.11 | 29.75 | 24.34 | 20.73 | 23.44 | 36.21 |
| 3 | 63.10 | 33.35 | 22.54 | 15.32 | 19.83 | 18.03 | 28.70 |
| 4 | 43.27 | 27.94 | 27.94 | 48.68 | 54.09 | 54.09 | 42.67 |
| 5 | 100.10 | 72.11 | 48.68 | 22.54 | 55.89 | 75.72 | 62.51 |
| 6 | 64.00 | 54.99 | 48.68 | 36.96 | 30.65 | 47.78 | 47.18 |
| 7 | 38.76 | 24.34 | 10.82 | 20.73 | 21.63 | 24.34 | 23.44 |
| 8 | 30.65 | 25.24 | 20.73 | 16.23 | 17.13 | 36.96 | 24.49 |
| 9 | 9.01 | 18.03 | 13.52 | 9.01 | 11.72 | 9.92 | 11.87 |
| Average Deer Per Square Mile Over Entire Study Area | 50.98 | 43.37 | 28.35 | 27.74 | 31.55 | 37.56 | 36.59 |

Table 3-3. Relative Mule Deer Use Factors for the Plot Descriptor Elevation in the Winter Sampling Period.

| Elevation[1/] (Ft. Above Sea Level) | No. Plots | Winter Relative Use Factor 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | Avg. |
|---|---|---|---|---|---|---|---|---|
| 6000 | 8 | 0.309 | 1.455 | 1.670 | 1.137 | 0.500 | 0.000 | 0.845 |
| 6500 | 491 | 1.016 | 1.067 | 0.968 | 0.675 | 0.667 | 0.792 | 0.864 |
| 7000 | 438 | 1.014 | 1.109 | 1.233 | 0.968 | 1.263 | 1.414 | 1.167 |
| 7500 | 267 | 1.057 | 0.763 | 0.834 | 1.550 | 1.199 | 1.200 | 1.101 |
| 8000 | 56 | 0.575 | 0.624 | 0.159 | 1.462 | 1.000 | 0.386 | 0.701 |

1/ Elevations represent the lower limits of the ranges within which plots are grouped: 8 plots are between 6,000 and 6,500 feet.

elevation tend to show that deer prefer to winter in areas of best available forage when snow depths allow movement at those higher elevations.

Table 3-4 presents mule deer relative use factors for the plot descriptor slope. The slope steepness most preferred over the six-winter sample period was between 10 and 20 degrees. The greater use of this slope increment over others is probably due to several reasons. Slopes less than 20°, though facing in a southerly direction, would receive less solar radiation and would tend to have deeper snow, which may preclude deer use. A southerly slope steeper than 20° may receive so much solar radiation that the area would be too xeric to provide moisture for adequate growth of forage. Mule deer prefer to be on a relatively steep slope so that they can avoid predators. The high speed locomotion used by mule deer has evolved into a situation where all four feet hit the ground at the same time providing good traction in loose, steep slopes. This type of locomotion enables deer to avoid predators on open hillsides where traction of the predator may not be equal to that of the deer. A slope of 20 degrees may offer more of these preferred factors than do other slopes.

Relative mule deer use factors for the plot descriptor aspect over the six-winter sampling period are presented in Table 3-5. Overall, slopes with aspects from northwest through north- to southeast-facing receive more deer use over other aspects. This use is probably a result of the higher moisture available for growth of forage on these aspects. Slopes with a south- or west-facing component receive more solar radiation and are generally drier with less vegetative cover present for deer use. South- or west-facing slopes may be important as snow-free travel lanes between bedding and feeding areas but they provide little forage and deer apparently spend less time there.

In general, mule deer should prefer those habitats in which the necessary requisites to maintain adequate body condition through the winter can be obtained with the least energy expenditure (RBOSC 1983a). The mixed brush

Table 3-4. Relative Mule Deer Use Factors for the Plot Descriptor Slope in the Winter Sampling Period.

| Slope[1/] (Degrees) | No. Plots | Winter Relative Use Factor 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | Avg. |
|---|---|---|---|---|---|---|---|---|
| 10 | 774 | 1.030 | 0.961 | 1.015 | 0.922 | 0.955 | 0.886 | 0.961 |
| 20 | 210 | 1.250 | 1.335 | 1.405 | 1.121 | 1.301 | 1.526 | 1.323 |
| 30 | 133 | 0.954 | 0.927 | 0.956 | 1.617 | 1.096 | 1.380 | 1.155 |
| 40 | 75 | 0.660 | 1.086 | 0.356 | 0.910 | 0.853 | 1.152 | 0.836 |
| 50 | 68 | 0.364 | 0.471 | 0.393 | 0.401 | 0.588 | 0.371 | 0.431 |

1/ The slope components represent slope angles: 10 = 0-10°, 20 = 10-20°, etc.

Table 3-5. Relative Mule Deer Use Factors for the Plot Descriptor Aspect in the Winter Sampling Period.

| Aspect | No. Plots | Winter Relative Use Factor 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | Avg. |
|---|---|---|---|---|---|---|---|---|
| North | 142 | 1.485 | 1.011 | 1.224 | 0.877 | 1.167 | 1.440 | 1.201 |
| Northeast | 280 | 1.165 | 0.941 | 0.786 | 1.271 | 0.941 | 0.847 | 0.992 |
| East | 68 | 0.917 | 1.526 | 1.152 | 1.622 | 1.231 | 1.800 | 1.375 |
| Southeast | 140 | 0.996 | 0.895 | 1.133 | 1.561 | 1.373 | 1.016 | 1.162 |
| South | 145 | 0.695 | 0.957 | 0.945 | 0.717 | 0.712 | 0.745 | 0.795 |
| Southwest | 170 | 0.576 | 0.638 | 0.610 | 0.561 | 0.877 | 0.542 | 0.634 |
| West | 73 | 0.536 | 0.452 | 0.297 | 0.531 | 0.814 | 0.900 | 0.588 |
| Northwest | 60 | 0.879 | 1.265 | 0.968 | 0.890 | 0.725 | 0.823 | 0.925 |
| Flat | 182 | 0.920 | 0.843 | 0.949 | 0.721 | 0.787 | 0.791 | 0.835 |

and mixed brush/pinyon-juniper habitats are therefore the vegetation types where high deer use would be expected. Use of other vegetation types may result from inaccessability of preferred sites, searching for forage and protection, and from other factors. A shift in vegetation type use among years can be seen from the relative use values in Table 3-6. The winter of 1978/79 was very severe with deep snow precluding deer use of much of the winter range and probably all north-facing slopes where the mixed brush type is common. The pinyon-juniper type offers little forage to deer and is generally one of the least preferred types, but it occurs on south- and west-facing slopes where snow depths are typically low. During the winter of 1978-79 (1979 in Table 3-6) the deer relative use factor for the mixed brush type was lowest of all six winter periods while the pinyon-juniper type use was the highest. This use pattern probably reflects the inaccessability of the mixed brush type and the accessability of the pinyon-juniper type during that winter of deep snow. Limited snow depths under the pinyon-juniper canopy allowed for deer use and the canopy density probably offered some protection from the severe cold of that winter. The mild winter of 1981 resulted in almost the opposite use of vegetation types, with a high relative use factor for mixed brush and low use factor for pinyon-juniper.

Variable mule deer use as indicated by habitat descriptor components over the six-winter sampling period provides a basis for design of reclamation and impact mitigation plans. Reclamation of disturbed areas into deer habitat should be directed toward providing as many of the preferred descriptor components as possible while assuring adequate habitat necessary for survival during "critical" winters. Habitat mitigation, if conducted in an area of "normal winter range", should be directed toward providing habitat necessary for survival during "critical" winters.

Table 3-6. Relative Mule Deer Use Factors for the Plot Descriptor Vegetation Type in the Winter Sampling Period.

| Vegetation Type | No. Plots | Winter Relative Use Factor 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | Avg. |
|---|---|---|---|---|---|---|---|---|
| Mixed Brush | 366 | 1.217 | 0.914 | 1.052 | 1.525 | 1.308 | 1.377 | 1.232 |
| Mixed Brush - Pinyon-Juniper | 277 | 0.834 | 1.600 | 1.239 | 1.100 | 0.993 | 1.144 | 1.152 |
| Pinyon-Juniper | 106 | 0.495 | 0.767 | 0.445 | 0.331 | 0.370 | 0.272 | 0.447 |
| Sagebrush | 254 | 1.047 | 0.920 | 1.214 | 0.809 | 0.996 | 0.950 | 0.989 |
| Sagebrush-Pinyon-Juniper | 208 | 1.185 | 0.717 | 0.802 | 0.711 | 0.906 | 1.177 | 0.916 |
| Other Vegetation Type | 49 | 0.404 | 0.297 | 0.273 | 0.278 | 0.571 | 0.294 | 0.353 |

B. Mule Deer Road Kill Survey

1. Objectives

The objective of this program is to determine mule deer mortality due to collisions with vehicles along Rio Blanco County Road 24, from the Piceance Creek Road to Tract C-a.

2. Methods

The methods for collection of these data are described in RBOSC MDP Monitoring Report 5 (RBSOC 1980).

3. Results an Discussion

Four mule deer road kills were found along Rio Blanco Country Road 4 during 1983. These deer were an adult male found at milepost 7.0 on February 10, an adult female at milepost 1.2 on April 15, an immature male at milepost 6.0 on December 4, and an immature female at milepost 13.0 on December 12. The number of road kills per year should continue to remain low during RBOSC's suspension period so long as traffic volume along County Road 24 does not increase due to other activity in the region.

D. Threatened, Endangered and Protected Species

Baseline, interim, and MDP environmental studies indicate that Tract C-a and the surrounding area does not provide critical habitat for any state or federally protected endangered wildlife species. The only endangered species regularly observed in the vicinity of Tract C-a is the bald eagle. This species is occasionally seen foraging in the area and feeding on dead deer during winter months. Golden eagles and other raptors protected in Colorado were seen during the reporting period. Some of these species are year long residents and may nest in the area. No nests are known to occur near present Tract C-a development activities.

## 3.3 SUMMARY

The components of the Terrestrial Monitoring Program examined during the 1983 reporting period included vegetation mapping and stress, mule deer density and mule deer road kill studies. Opportunistic observations of threatened, endangered and protected species were also made.

Plant community stress conditions were assessed using color infrared (CIR) aerial photography. Because of the short duration of the in-situ retort burns and because mine dewatering/reinjection activities had the potential for more readily identifiable impacts as evidenced via CIR photography, the focus of between year comparisons was directed at changes in "moisture regime" within major drainages on and adjacent to Tract C-a. Variations in "moisture regimes", as indicated by changes in infrared response of vegetation, were noted for Stake Springs Draw, Corral Gulch, Big Duck Creek and Yellow Creek between 1974, 1979, 1980 and 1981.

Using the 1974 photography as a base case, eight areas of increased and/or decreased moisture were identified in Stake Springs Draw, six in Corral Gulch, eight in Duck Creek and four in the Yellow Creek Drainage. Because most changes observed in Stake Springs Draw and Big Duck Creek appeared to be related to increases in moisture, it is reasonable to assume that mine dewatering activities and the associated drawdown of the upper aquifer had little if any effect on the moisture regimes within these drainages. It is possible that reinjection of dewatering waters may have influenced moisture regimes in both Stake Springs Draw to the southeast of Tract C-a and in Corral Gulch immediately east of Tract C-a. Surface discharge of water also may have influenced the moisture regime in Corral Gulch.

The most pronounced areas of change in the lower portions of Corral Gulch and the upper reaches of Yellow Creek appeared to be related to variations in irrigation. To the extent that surface discharge of Tract C-a mine dewatering water made additional irrigation possible, these changes may be indirectly associated with tract operations.

The use of CIR photography to monitor vegetation stress is confounded by the subjectivity associated with photographic interpretation, the year-to-year variations in photographic quality associated with color balance and atmospheric conditions, and the questionable sensitivity of CIR photographs in upland areas. Based on results of these studies, the use of CIR photography for routine monitoring of vegetation stress is of questionable utility for Tract C-a.

The mule deer density during the winter of 1982-83 ranged from 10 to 76 deer per square mile, with an average density for the entire area of 38 deer/mi$^2$. This density is slightly higher than the 37 deer/mi$^2$ noted during winter periods from 1978-1983. As in the past, Block 5 which encompasses Tract C-a had the greatest density of deer, perhaps due to habitat diversity.

Relative use factors based on elevation, slope steepness, slope aspect, and vegetation type were calculated and compared among years. The elevational range from 7,000-8,000 feet had the highest proportion of pellet groups over the six winters studied, but variations among years were evident and appeared to be related to the severity of winters. Slope angles between 10 and 20 degrees seemed to be favored over all others. The combined influences of snow depth, available forage and predator avoidance may make this slope angle increment more attractive than others to mule deer. Slope aspects ranging from northwest through north- to southeast-facing received more deer use than other aspects. This apparent preference seemed to be related to available forage, as supported by relative use factors based on vegetation type. However, a shift in vegetation type use among years was also evident. During severe winters mixed brush vegetation on northerly-facing slopes is generally unavailable. This was the case during 1978-1979 when deep snow limited use of the mixed brush type. The mild winter of 1981 allowed relatively unencumbered use of the mixed brush type because of shallow snow depths.

Variable mule deer use, as indicated by relative use factors for the habitat descriptor components, provides a basis for design of reclamation and impact mitigation plans. Reclamation of disturbed areas into deer habitat should be directed toward providing as many of the preferred habitat components as possible while assuring adequate habitat necessary for survival during "critical" winters. Habitat mitigation, if conducted in an area of "normal winter range", should be directed toward providing habitat necessary for survival during "critical" winters.

Four mule deer road kills were found along Rio Blanco County Road 24 during 1983, including an adult male, an adult female, an immature male and an immature female. Road kills should remain relatively low during RBOSC's lease suspension period provided that traffic related to other activity in the region does not increase.

During 1983, the golden eagle and other raptors protected in Colorado were observed in the vicinity of Tract C-a. No nests of any protected raptors were known to occur near present Tract C-a development activities.

## LITERATURE CITED


Neff, D.J. 1968. The pellet group count technique for big game trend, census, and distribution: a review. J. Wildl. Manag. 32(3): 597-614.

Overton, W.S. 1971. Estimating the numbers of animals in wildlife populations. p. 403-456 in R.H. Giles, Jr. (Ed) Wildlife Management Techniques. Edward Bros., Inc., Ann Arbor, Michigan. (For the Wildlife Society).

Rio Blanco Oil Shale Company. 1978. Modular development phase monitoring report 1, September 1977 - November 1977. Gulf Oil Corp. and Standard Oil Co. (Indiana).

_____. 1980. Modular development phase monitoring report 5, December 1978 - November 1979. Gulf Oil Corp. and Standard Oil Co. (Indiana).

_____. 1981. Modular development phase monitoring report 7, December 1979 - December 1980. Gulf Oil Corp. and Standard Oil Co. (Indiana).

_____. 1983a. Modular development phase monitoring report 11, January - December 1982. Gulf Oil Corp. and Standard Oil Co. (Indiana).

_____. 1983b. Modular development phase monitoring program scope of work. Revision 7.0 Gulf Oil Corp. and Standard Oil Co. (Indiana).

# SECTION 4
# AQUATIC STUDIES

## 4.0 INTRODUCTION

The MDP Aquatic Monitoring Program is designed to provide information on the aquatic ecosystems in the vicinity of Tract C-a. The primary purpose of this program is to identify and measure the potential effects on the stream systems that may be the result of oil shale development.

Three sampling locations comprised the Aquatic Monitoring Program in 1983. They are described as follows, and presented in Figure 4-1:

- Station CG-1 at the confluence of Corral and Box Elder Gulches
- Station YC-1 on Yellow Creek approximately 100 meters below the confluence of Stake Springs Draw and Corral Gulch
- Station YC-2 on Yellow Creek 100 meters south of the confluence with Barcus Creek, and approximately 10 kilometers upstream from the confluence of the White River and Yellow Creek

Table 4-1 lists the parameters and frequency of the biotic and abiotic data collected as part of this program. Section 4 provides the results of the 1983 MDP Aquatic Studies and comparisons of these results to those data collected in previous years.

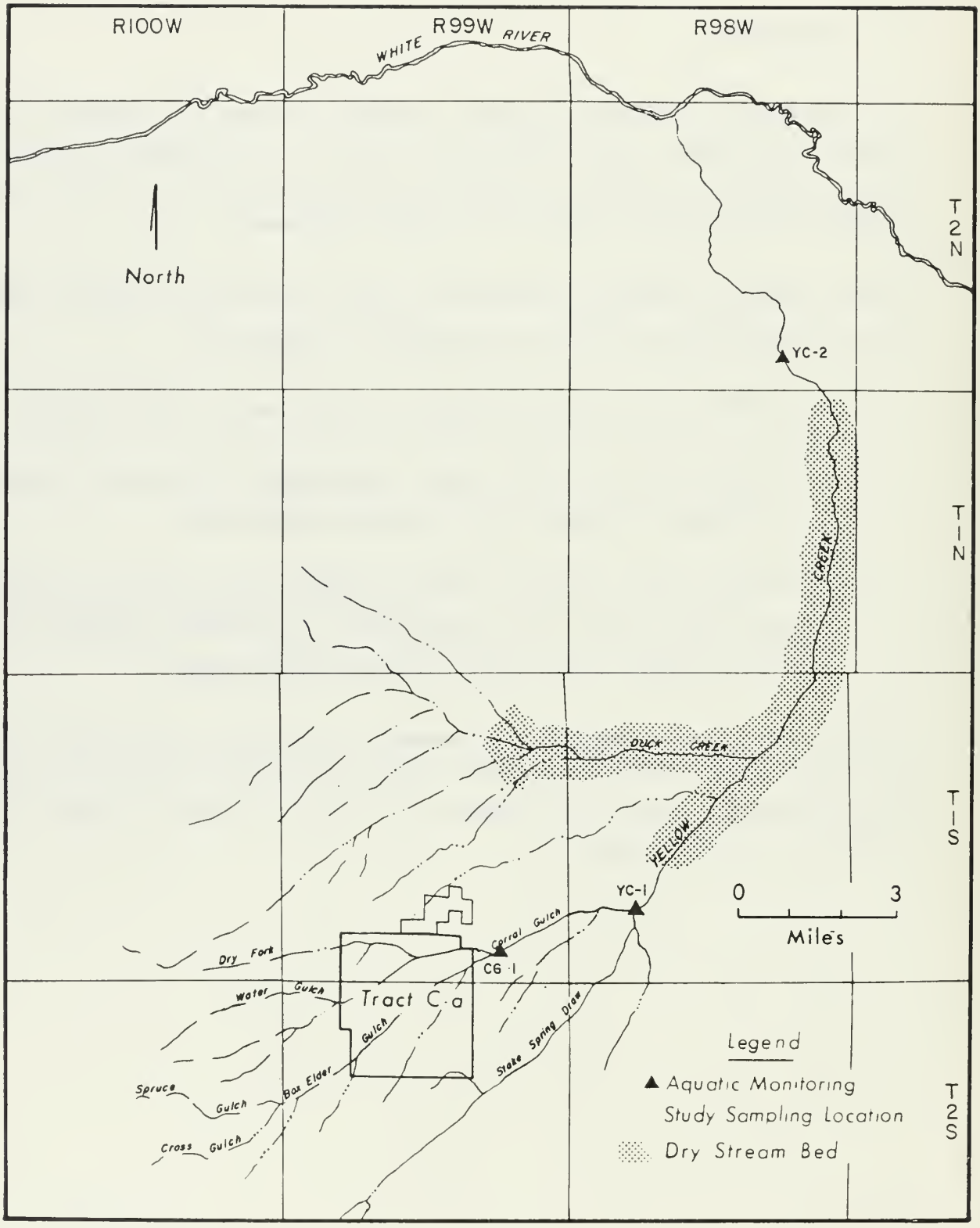



Figure 4-1. MDP Aquatic Monitoring Station Locations

Table 4-1. Aquatic Ecology Monitoring Program Sampling Schedule and Parameter List.

| Parameter | Location | Frequency |
|---|---|---|
| ABIOTIC COMPONENTS: | | |
| Physical Measurements | All Stations (see Figure 4.1) | 3 Times/yr (April, July, October) |
| Total Dissolved Solids | | |
| Stream Velocity | | |
| Turbidity | | |
| Dissolved Oxygen | | |
| pH | | |
| Specific Conductance | | |
| Depth | | |
| Width | | |
| Stream Substrate | | |
| Suspended Solids | | |
| Temperature | | |
| Alkalinity | | |
| Basic Water Quality Measurements | All Stations | 3 Times/yr (April, July, October) |
| Calcium | | |
| Magnesium | | |
| Potassium | | |
| Sodium | | |
| Bicarbonate | | |
| Chloride | | |
| Nitrate | | |
| Sulfate | | |
| Fluoride | | |
| Ammonia | | |
| Total Phosphate | | |
| Boron | | |
| Silica ($SiO_2$) | | |
| Iron | | |
| Dissolved Organic Carbon | | |
| Arsenic | | |
| Selenium | | |
| Vanadium | | |
| Molybdenum | | |
| Mercury | | |
| BIOTIC COMPONENTS: | | |
| Benthic Macroinvertebrates | | |
| Species Composition | All Stations | 3 Times/yr (April, July, October) |
| Density | | |
| Diversity | | |

## 4.1 ABIOTIC COMPONENTS

### A. Stream Physical Measurements

#### 1. Objectives and Rationale

The stream physical measurements program is designed to monitor selected physical parameters at MDP aquatic sampling stations, and relate these data to water quality and aquatic biota conditions. The parameters selected for monitoring are those which may be affected by project activities and which may influence the distribution, abundance, and composition of aquatic biota in the study area. Chemical parameters, such as dissolved oxygen, which were measured in the field in conjunction with the physical measurements are also presented in this section.

#### 2. Methods

The methods used to collect stream physical data are described in the RBOSC Environmental Monitoring Program Scope of Work and are not repeated herein (RBOSC 1983).

#### 3. Results and Discussion

A comparison of the 1983 physical measurement means for each station with the historical data for that station is presented in Table 4-2. These data indicate that a high degree of variability exists among the three stations sampled, and that a progressive increase in conductivity occurs with downstream movement from Tract C-a. The stream physical data collected during the 1983 field season are presented in Appendix 4-1.1.

Figures 4-2 through 4-5 graphically display the seasonal and station distribution for physical data collected in the 1983 field season. Figure 4-2 shows that a high degree of seasonal variability exists for the water temperature data. Table 4-3 indicates that there are no significant

Table 4-2. Comparison of Stream Physical Data Mean Values for 1983 with Means from the Data Base for Previous Years at Three Sampling Stations.

| | Station Mean | | | | | |
|---|---|---|---|---|---|---|
| | CG-1 | | YC-1 | | YC-2 | |
| Parameter | Data Base | 1983 | Data Base | 1983 | Data Base | 1983 |
| Temperature | 13.2 | 12.7 | 12.5 | 12.0 | 14.5 | 11.7 |
| Conductivity | 1329.3 | 1333.0 | 1696.9 | 1681.0 | 2589.8 | 2517.0 |
| Dissolved Oxygen | 7.8 | 11.6 | 11.0 | 12.9 | 10.3 | 11.2 |
| pH | 7.6 | 7.6 | 7.5 | 8.2 | 7.6 | 8.1 |

differences over the station and report year main effects, while a significant difference among seasons was indicated. Overall, any differences among the three independent variables of station, report year, and season must be attributed to natural variation, because there were no surface discharges on Tract C-a during 1983.

Figure 4-3 illustrates that the specific conductance data collected in 1983 continues to show an increase with distance downstream from Tract C-a. Tables 4-2 and 4-3 each indicate that changes among years are evident for the specific conductance data collected thus far in the aquatic ecology program. Stations continue to be both unique and significantly independent from each other, as demonstrated in Table 4-3 and Appendix 4-1.2. A seasonal difference was found that indicates summer specific conductances to be significantly lower than the spring or fall seasons (Appendix 4-1.2:Table 4-3).

Figure 4-4 presents the dissolved oxygen data collected in 1983. These data indicate a station difference may exist for dissolved oxygen data. ANOVA results (Table 4-3) indicate that a high degree of significance among

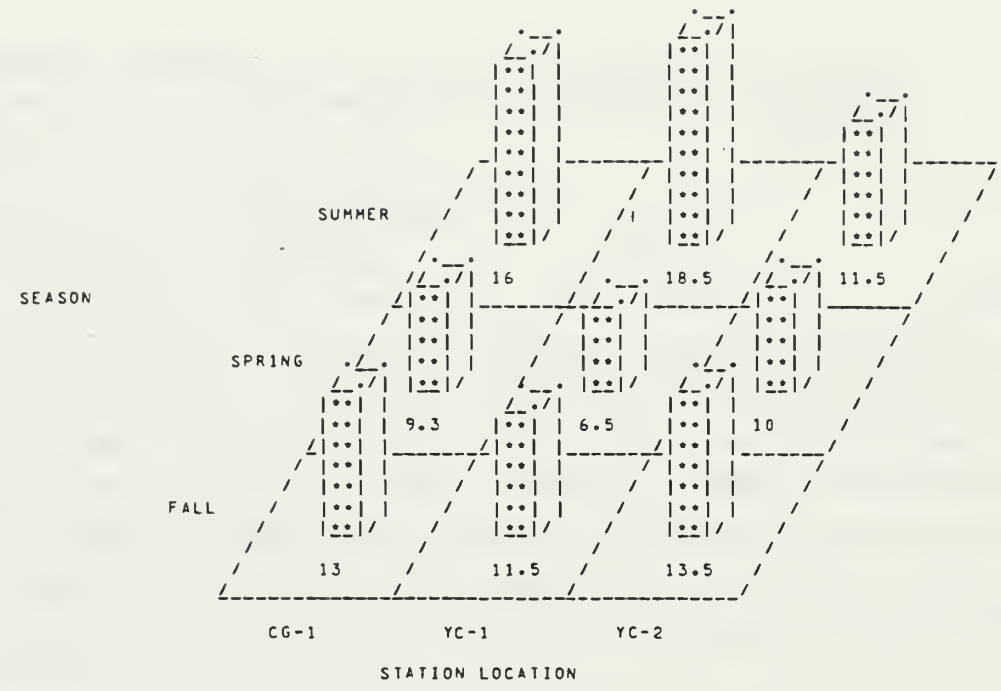



Figure 4-2. Water Temperature Measurements made during the 1983 field season.

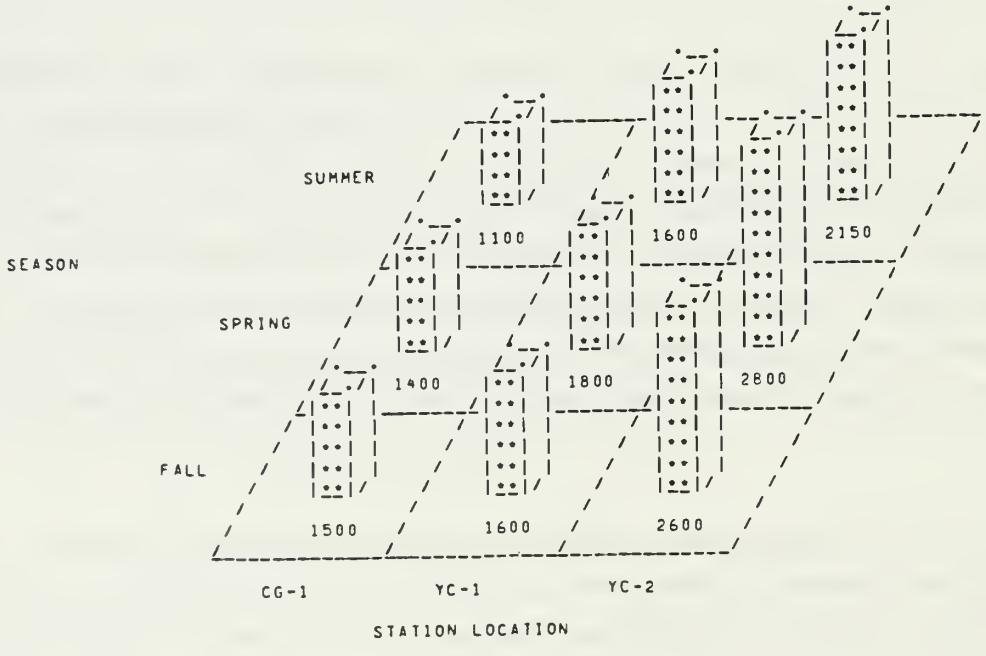



Figure 4-3. Specific Conductance Measurements made during the 1983 field season.

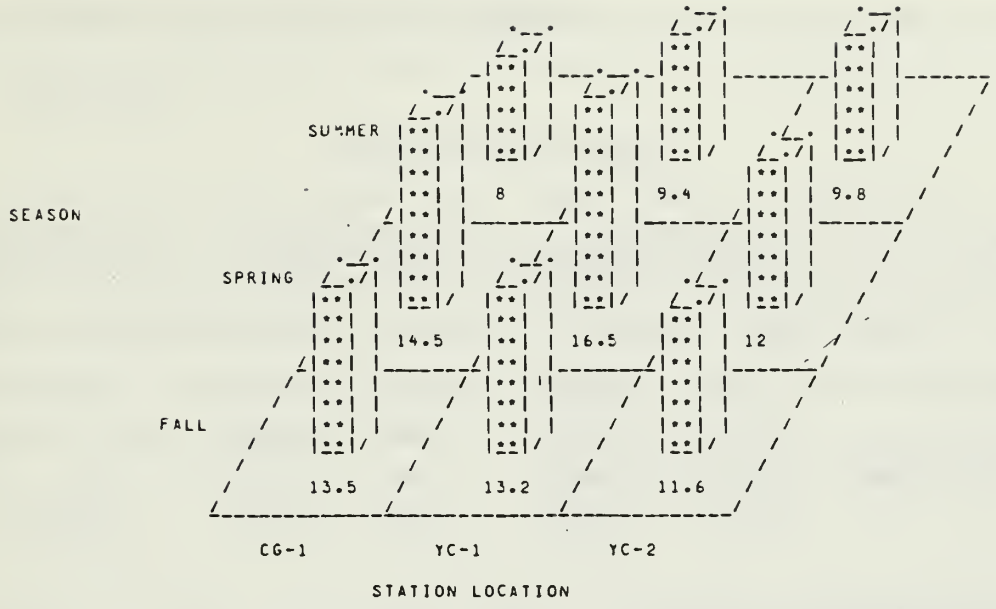



Figure 4-4. Dissolved Oxygen Measurements made during the 1983 field season.

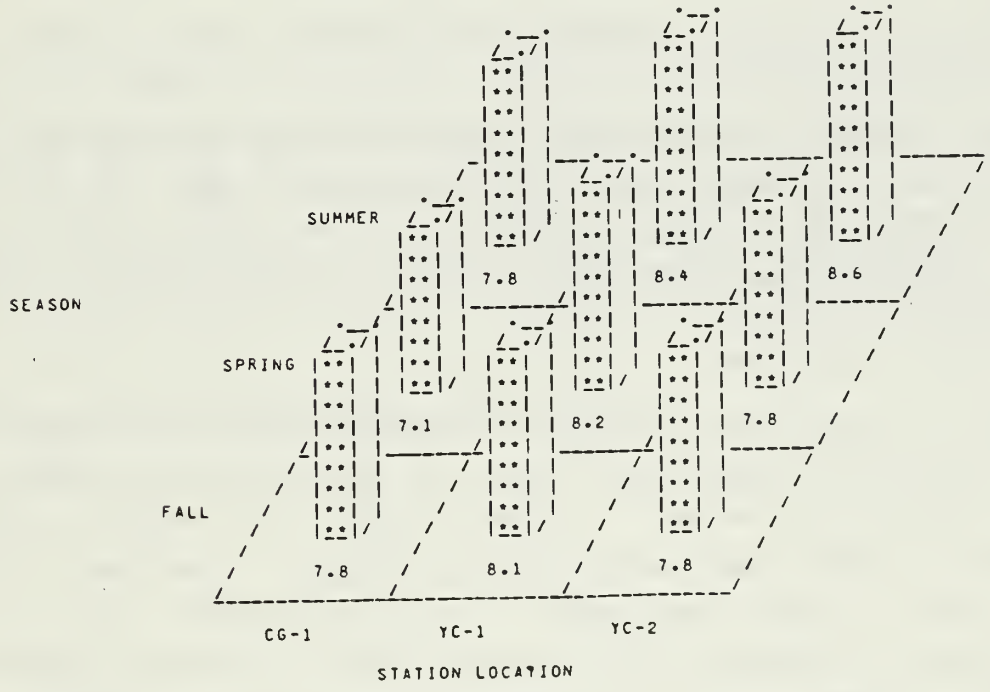



Figure 4-5. Ph Measurements made during the 1983 field season.

Table 4-3. Analysis of Variance Summary Table for the Stream Physical Data.

| Parameter Measured | Source of Variation[1/] Station F Value | Station PR>F | Report Year F Value | Report Year PR>F | Season F Value | Season PR>F |
|---|---|---|---|---|---|---|
| Temperature | 0.90 | 0.4167 | 0.73 | 0.6803 | 7.77** | 0.0021 |
| Conductivity | 219.60** | 0.0001 | 2.06 | 0.0697 | 7.23** | 0.0029 |
| Dissolved Oxygen | 10.94** | 0.0003 | 1.92 | 0.0898 | 1.04 | 0.3661 |
| pH | 13.31** | 0.0001 | 3.40** | 0.0062 | 5.36** | 0.0107 |

* Significant at $\alpha = 0.05$

** Significant at $\alpha = 0.025$

1/ Significant main effect differences are evaluated with a Duncans Multiple Range Tests. Results of these tests are presented in Appendix 4-1.2.

station locations exists; Duncan's Multiple Range Test results, Appendix 4-1.2, show that station CG-1 has significantly lower dissolved oxygen readings than the two downstream stations YC-1 and YC-2. Table 4-2 shows that dissolved oxygen data collected in 1983 and the data base average are similar.

Figure 4-5 shows that the pH data collected in 1983 differs among stations. This observation is confirmed in Table 4-3, where differences among stations are statistically evident. Stream pH data, like specific conductance, exhibits a slight downstream progressive increase. Significant differences over years and season were seen in the pH data (Table 4-3). Due to the statistically different year and season effects, pH data may not be a good indicator parameter for long term monitoring in ephermeral stream systems.

B. Stream Water Chemistry Measurements

1. Objectives

The objective of the stream basic water quality (BWQ) data (Table 4-1) collection effort is to evaluate changes in water chemistry downstream from Tract C-a. Major changes in the water chemistry values could affect the benthic macroinvertebrate population. Therefore, water chemistry data can be used to compare and evaluate changes in the biological conditions observed at each sampling site.

2. Methods

The methods used to collect the stream water chemistry samples are described in the RBOSC approved Scope of Work and are not presented here (RBOSC 1983).

3. Results and Discussion

Water chemistry data collected for Stations CG-1, YC-1, and YC-2 are summarized in Tables 4-4 through 4-9. Tables 4-4, 4-6, and 4-8 present the univariate summaries for 1983 data for each station. Tables 4-5, 4-7, and 4-9 present 1980-1982 data base summaries for each station. Data for each of the three seasons sampled in 1983 are presented in Appendix 4-1.3. Inspection of these tables indicates that sodium, bicarbonate, total dissolved solids, and alkalinity all increase in concentration with distance downstream from Tract C-a. This pattern has been previously observed and represents the natural character of the system.

TABLE 4-4 . BASIC WATER QUALITY CONSTITUENTS (MG/L) SUMMARY FOR DATA COLLECTED AT STATION CG-1, IN 1983.

AQUATIC ECOLOGY BASIC WATER QUALITY CONSTITUENTS

| PARAMETER | N | MEAN | STD | MAX | MIN | P10 | P90 |
|---|---|---|---|---|---|---|---|
| CALCIUM | 3 | 86.33 | 4.51 | 91.00 | 82.00 | 82.00 | 91.00 |
| MAGNESIUM | 3 | 74.67 | 8.14 | 84.00 | 69.00 | 69.00 | 84.00 |
| SODIUM | 3 | 170.00 | 17.32 | 180.00 | 150.00 | 150.00 | 180.00 |
| POTASSIUM | 3 | 1.49 | 0.16 | 1.60 | 1.30 | 1.30 | 1.60 |
| IRON | 3 | 0.03 | 0.07 | 0.07 | 0.05 | 0.05 | 0.07 |
| BICARBONATE | 3 | 545.00 | 28.93 | 566.00 | 512.00 | 512.00 | 566.00 |
| CARBONATE | 3 | 5.67 | 11.55 | 19.00 | 1.00 | 1.00 | 19.00 |
| SULFATES | 3 | 417.00 | 51.39 | 476.00 | 382.00 | 382.00 | 476.00 |
| CHLORIDE | 3 | 12.30 | 2.36 | 14.00 | 9.60 | 9.60 | 14.00 |
| TOT DIS SOLIDS | 3 | 1086.33 | 74.00 | 1171.00 | 1034.00 | 1034.00 | 1171.00 |
| ALKALINITY | 3 | 472.67 | 30.73 | 501.00 | 440.00 | 440.00 | 501.00 |
| PHOSPHATE | 3 | 0.05 | 0.00 | 0.05 | 0.05 | 0.05 | 0.05 |
| AMMONIA | 0 | . | . | . | . | . | . |
| NITRATE | 3 | 0.53 | 0.06 | 0.60 | 0.50 | 0.50 | 0.60 |
| FLOURIDE | 0 | . | . | . | . | . | . |
| DIS ORG CARBON | 3 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| ARSENIC | 3 | 0.24 | 0.14 | 0.34 | 0.08 | 0.08 | 0.34 |
| BORON | 3 | 0.30 | 0.00 | 0.30 | 0.30 | 0.30 | 0.30 |
| MERCURY | 3 | 0.03 | 0.12 | 0.10 | 0.10 | 0.10 | 0.10 |
| MOLYBDENUM | 3 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| SELENIUM | 3 | 21.67 | 1.53 | 23.00 | 20.00 | 20.00 | 23.00 |
| SILICA | 3 | 0.10 | 0.00 | 0.10 | 0.10 | 0.10 | 0.10 |

TABLE 4-5 . BASIC WATER QUALITY CONSTITUENTS (MG/L) SUMMARY FOR DATA COLLECTED AT STATION CG-1.

AQUATIC ECOLOGY BASIC WATER QUALITY CONSTITUENTS

| PARAMETER | N | MEAN | STD | MAX | MIN | P10 | P90 |
|---|---|---|---|---|---|---|---|
| CALCIUM | 9 | 81.67 | 4.56 | 91.00 | 76.00 | 76.00 | 91.00 |
| MAGNESIUM | 9 | 71.33 | 6.46 | 84.00 | 65.00 | 65.00 | 84.00 |
| SODIUM | 9 | 167.78 | 9.72 | 180.00 | 150.00 | 150.00 | 180.00 |
| POTASSIUM | 9 | 1.38 | 0.13 | 1.60 | 1.27 | 1.27 | 1.60 |
| IRON | 9 | 0.02 | 0.05 | 0.07 | 0.05 | 0.05 | 0.07 |
| BICARBONATE | 9 | 550.00 | 25.91 | 582.00 | 506.00 | 506.00 | 582.00 |
| CARBONATE | 9 | 1.22 | 6.67 | 19.00 | 1.00 | 1.00 | 19.00 |
| SULFATES | 9 | 383.39 | 38.28 | 476.00 | 347.00 | 347.00 | 476.00 |
| CHLORIDE | 9 | 11.37 | 2.26 | 15.10 | 9.38 | 9.38 | 15.10 |
| TOT DIS SOLIDS | 9 | 1037.89 | 63.39 | 1171.00 | 944.00 | 944.00 | 1171.00 |
| ALKALINITY | 9 | 471.00 | 23.07 | 501.00 | 435.00 | 435.00 | 501.00 |
| PHOSPHATE | 9 | 0.02 | 0.09 | 0.23 | 0.05 | 0.05 | 0.23 |
| AMMONIA | 0 | . | . | . | . | . | . |
| NITRATE | 9 | 0.81 | 0.83 | 3.00 | 0.35 | 0.35 | 3.00 |
| FLOURIDE | 3 | 0.42 | 1.42 | 0.75 | 2.00 | 2.00 | 0.75 |
| DIS ORG CARBON | 9 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| ARSENIC | 9 | 0.20 | 0.16 | 0.44 | 0.01 | 0.01 | 0.44 |
| BORON | 9 | 0.17 | 0.15 | 0.00 | 0.30 | 0.30 | 0.00 |
| MERCURY | 9 | 0.10 | 0.10 | 0.10 | 0.30 | 0.30 | 0.10 |
| MOLYBDENUM | 9 | 0.06 | 0.16 | 0.01 | 0.50 | 0.50 | 0.01 |
| SELENIUM | 8 | 21.75 | 3.65 | 26.00 | 14.00 | 14.00 | 26.00 |
| SILICA | 8 | 0.30 | 0.21 | 0.10 | 0.50 | 0.50 | 0.10 |

TABLE 4-6 . BASIC WATER QUALITY CONSTITUENTS (MG/L) SUMMARY FOR DATA COLLECTED AT STATION YC-1, IN 1983.

AQUATIC ECOLOGY BASIC WATER QUALITY CONSTITUENTS

| PARAMETER | N | MEAN | STD | MAX | MIN | P10 | P90 |
|---|---|---|---|---|---|---|---|
| CALCIUM | 3 | 91.67 | 13.05 | 102.00 | 77.00 | 77.00 | 102.00 |
| MAGNESIUM | 3 | 102.33 | 7.51 | 110.00 | 95.00 | 95.00 | 110.00 |
| SODIUM | 3 | 200.00 | 20.00 | 220.00 | 180.00 | 180.00 | 220.00 |
| POTASSIUM | 3 | 1.92 | 0.16 | 2.10 | 1.80 | 1.80 | 2.10 |
| IRON | 3 | 0.03 | 0.07 | 0.08 | 0.05 | 0.05 | 0.08 |
| BICARBONATE | 3 | 580.33 | 55.01 | 636.00 | 526.00 | 526.00 | 636.00 |
| CARBONATE | 3 | 1.00 | 0.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| SULFATES | 3 | 567.33 | 54.63 | 629.00 | 525.00 | 525.00 | 629.00 |
| CHLORIDE | 3 | 18.60 | 2.78 | 20.40 | 15.40 | 15.40 | 20.40 |
| TOT DIS SOLIDS | 3 | 1322.67 | 14.22 | 1339.00 | 1313.00 | 1313.00 | 1339.00 |
| ALKALINITY | 3 | 492.67 | 47.50 | 540.00 | 445.00 | 445.00 | 540.00 |
| PHOSPHATE | 3 | 0.05 | 0.00 | 0.05 | 0.05 | 0.05 | 0.05 |
| AMMONIA | 0 | . | . | . | . | . | . |
| NITRATE | 3 | 0.43 | 0.15 | 0.60 | 0.30 | 0.30 | 0.60 |
| FLOURIDE | 0 | . | . | . | . | . | . |
| DIS ORG CARBON | 3 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| ARSENIC | 3 | 0.28 | 0.09 | 0.34 | 0.18 | 0.18 | 0.34 |
| BORON | 3 | 0.30 | 0.00 | 0.30 | 0.30 | 0.30 | 0.30 |
| MERCURY | 3 | 0.10 | 0.00 | 0.10 | 0.10 | 0.10 | 0.10 |
| MOLYBOENUM | 3 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| SELENIUM | 3 | 18.33 | 2.31 | 21.00 | 17.00 | 17.00 | 21.00 |
| SILICA | 3 | 0.10 | 0.00 | 0.10 | 0.10 | 0.10 | 0.10 |

TABLE 4-7 . BASIC WATER QUALITY CONSTITUENTS (MG/L) SUMMARY FOR DATA COLLECTED AT STATION YC-1.

AQUATIC ECOLOGY BASIC WATER QUALITY CONSTITUENTS

| PARAMETER | N | MEAN | STD | MAX | MIN | P10 | P90 |
|---|---|---|---|---|---|---|---|
| CALCIUM | 8 | 97.63 | 19.19 | 140.00 | 77.00 | 77.00 | 140.00 |
| MAGNESIUM | 8 | 108.13 | 22.97 | 160.00 | 82.00 | 82.00 | 160.00 |
| SODIUM | 8 | 215.00 | 20.00 | 240.00 | 180.00 | 180.00 | 240.00 |
| POTASSIUM | 8 | 2.17 | 0.38 | 2.70 | 1.70 | 1.70 | 2.70 |
| IRON | 8 | 0.07 | 0.26 | 0.69 | 0.05 | 0.05 | 0.69 |
| BICARBONATE | 8 | 605.25 | 66.45 | 686.00 | 500.00 | 500.00 | 686.00 |
| CARBONATE | 8 | 0.72 | 0.78 | 1.21 | 1.00 | 1.00 | 1.21 |
| SULFATES | 8 | 588.20 | 59.73 | 713.00 | 525.00 | 525.00 | 713.00 |
| CHLORIDE | 8 | 32.51 | 39.85 | 131.00 | 15.40 | 15.40 | 131.00 |
| TOT DIS SOLIDS | 8 | 1389.00 | 147.92 | 1728.00 | 1252.00 | 1252.00 | 1728.00 |
| ALKALINITY | 8 | 519.13 | 58.74 | 594.00 | 427.00 | 427.00 | 594.00 |
| PHOSPHATE | 8 | 0.02 | 0.08 | 0.16 | 0.05 | 0.05 | 0.16 |
| AMMONIA | 0 | . | . | . | . | . | . |
| NITRATE | 8 | 0.34 | 0.15 | 0.60 | 0.15 | 0.15 | 0.60 |
| FLOURIDE | 2 | 0.48 | 2.15 | 1.04 | 2.00 | 2.00 | 1.04 |
| DIS ORG CARBON | 8 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| ARSENIC | 8 | 0.44 | 0.35 | 1.22 | 0.18 | 0.18 | 1.22 |
| BORON | 8 | 0.17 | 0.14 | 0.00 | 0.30 | 0.30 | 0.00 |
| MERCURY | 8 | 0.12 | 0.07 | 0.10 | 0.30 | 0.30 | 0.10 |
| MOLYBDENUM | 8 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| SELENIUM | 8 | 17.50 | 2.83 | 21.00 | 12.00 | 12.00 | 21.00 |
| SILICA | 8 | 0.30 | 0.21 | 0.10 | 0.50 | 0.50 | 0.10 |

TABLE 4-8 . BASIC WATER QUALITY CONSTITUENTS (MG/L) SUMMARY FOR DATA COLLECTED AT STATION YC-2, IN 1983.

AQUATIC ECOLOGY BASIC WATER QUALITY CONSTITUENTS

| PARAMETER | N | MEAN | STD | MAX | MIN | P10 | P90 |
|---|---|---|---|---|---|---|---|
| CALCIUM | 3 | 66.67 | 3.06 | 70.00 | 64.00 | 64.00 | 70.00 |
| MAGNESIUM | 3 | 193.33 | 20.82 | 210.00 | 170.00 | 170.00 | 210.00 |
| SODIUM | 3 | 400.00 | 51.96 | 430.00 | 340.00 | 340.00 | 430.00 |
| POTASSIUM | 3 | 3.33 | 0.51 | 3.90 | 2.90 | 2.90 | 3.90 |
| IRON | 3 | 0.03 | 0.07 | 0.08 | 0.05 | 0.05 | 0.08 |
| BICARBONATE | 3 | 901.00 | 197.80 | 1069.00 | 683.00 | 683.00 | 1069.00 |
| CARBONATE | 3 | 10.67 | 20.21 | 34.00 | 1.00 | 1.00 | 34.00 |
| SULFATES | 3 | 989.33 | 99.51 | 1088.00 | 889.00 | 889.00 | 1088.00 |
| CHLORIDE | 3 | 31.50 | 1.80 | 33.50 | 30.00 | 30.00 | 33.50 |
| TOT DIS SOLIDS | 3 | 2211.33 | 256.63 | 2360.00 | 1915.00 | 1915.00 | 2360.00 |
| ALKALINITY | 3 | 794.00 | 145.43 | 899.00 | 628.00 | 628.00 | 899.00 |
| PHOSPHATE | 3 | 0.08 | 0.13 | 0.21 | 0.05 | 0.05 | 0.21 |
| AMMONIA | 0 | . | . | . | . | . | . |
| NITRATE | 3 | 0.67 | 0.29 | 1.00 | 0.50 | 0.50 | 1.00 |
| FLOURIDE | 0 | . | . | . | . | . | . |
| DIS ORG CARBON | 3 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| ARSENIC | 3 | 0.43 | 0.13 | 0.56 | 0.30 | 0.30 | 0.56 |
| BORON | 3 | 0.30 | 0.00 | 0.30 | 0.30 | 0.30 | 0.30 |
| MERCURY | 3 | 0.10 | 0.00 | 0.10 | 0.10 | 0.10 | 0.10 |
| MOLYBDENUM | 3 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| SELENIUM | 3 | 13.67 | 8.39 | 19.00 | 4.00 | 4.00 | 19.00 |
| SILICA | 3 | 0.10 | 0.00 | 0.10 | 0.10 | 0.10 | 0.10 |

TABLE 4-9 . BASIC WATER QUALITY CONSTITUENTS (MG/L) SUMMARY FOR DATA COLLECTED AT STATION YC-2.

AQUATIC ECOLOGY BASIC WATER QUALITY CONSTITUENTS

| PARAMETER | N | MEAN | STD | MAX | MIN | P10 | P90 |
|---|---|---|---|---|---|---|---|
| CALCIUM | 9 | 56.67 | 11.10 | 70.00 | 35.00 | 35.00 | 70.00 |
| MAGNESIUM | 9 | 194.67 | 39.00 | 270.00 | 130.00 | 130.00 | 270.00 |
| SODIUM | 9 | 413.67 | 30.35 | 443.00 | 340.00 | 340.00 | 443.00 |
| POTASSIUM | 9 | 3.57 | 1.34 | 7.00 | 2.50 | 2.50 | 7.00 |
| IRON | 9 | 0.02 | 0.06 | 0.08 | 0.05 | 0.05 | 0.08 |
| BICARBONATE | 9 | 907.56 | 147.27 | 1069.00 | 683.00 | 683.00 | 1069.00 |
| CARBONATE | 9 | 7.26 | 11.83 | 34.00 | 1.00 | 1.00 | 34.00 |
| SULFATES | 9 | 990.59 | 98.84 | 1195.00 | 889.00 | 889.00 | 1195.00 |
| CHLORIDE | 9 | 32.31 | 3.02 | 39.80 | 30.00 | 30.00 | 39.80 |
| TOT DIS SOLIDS | 9 | 2219.00 | 197.24 | 2584.00 | 1915.00 | 1915.00 | 2584.00 |
| ALKALINITY | 9 | 813.00 | 115.31 | 961.00 | 628.00 | 628.00 | 961.00 |
| PHOSPHATE | 9 | 0.11 | 0.10 | 0.26 | 0.05 | 0.05 | 0.26 |
| AMMONIA | 0 | . | . | . | . | . | . |
| NITRATE | 9 | 0.57 | 0.19 | 1.00 | 0.31 | 0.31 | 1.00 |
| FLOURIDE | 2 | 0.77 | 1.73 | 0.45 | 2.00 | 2.00 | 0.45 |
| DIS ORG CARBON | 9 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| ARSENIC | 9 | 0.48 | 0.17 | 0.79 | 0.26 | 0.26 | 0.79 |
| BORON | 9 | 0.18 | 0.15 | 0.00 | 0.30 | 0.30 | 0.00 |
| MERCURY | 9 | 0.12 | 0.07 | 0.10 | 0.30 | 0.30 | 0.10 |
| MOLYBDENUM | 9 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| SELENIUM | 9 | 12.22 | 5.65 | 19.00 | 4.00 | 4.00 | 19.00 |
| SILICA | 8 | 0.30 | 0.21 | 0.10 | 0.50 | 0.50 | 0.10 |

Stations CG-1 and YC-1 (Figure 4-1) exhibit higher calcium concentrations than the downstream Station YC-2 (Tables 4-4 to 4-9). Results from an Analysis of Variance Model (ANOVA), presented in Table 4-10, indicate that no seasonal or year-to-year variation is evident. The station source of variation was highly significant and the Duncan's Multiple Range Test results for calcium indicate that each station is independent and significantly different from the other (Appendix 4-1.4).

The mean magnesium distribution for 1983 for each of the three sampling stations is presented in Tables 4-4, 4-6, and 4-8. These tables show that Station YC-2 has substantially higher magnesium concentrations than those observed at Stations CG-1 and YC-1. Results from the ANOVA (Table 4-10) indicate that magnesium showed significant station and seasonal sources of variation, and a nonsignificant report year effect. The Duncan's Multiple Range Test results (Appendix 4-1.4) for magnesium indicate that the spring season is significantly higher than the other seasons (summer and fall), perhaps due to runoff during the spring. Each of the stations tested is significantly independent from the other (Appendix 4-1.4).

The mean potassium distributions for each station sampled in 1983 is presented in Tables 4-4, 4-6 and 4-8. These three tables, along with the data base summaries presented in Tables 4-5, 4-7, and 4-9, indicate that a progressive increase in downstream concentration exists. This pattern may be used to identify stations as independent and unique cohorts. The ANOVA summaries for potassium (Table 4-10) indicate no report year or seasonal differences exist, and only the station source of variation is significant. The Duncan's Multiple Range Test results indicate station cohorts above and below the dry segments of the Yellow Creek drainage system (Appendix 4-1.4).

The distributions presented for sodium, both in the 1983 data (Tables 4-4, 4-6, and 4-8) and the data base summaries (Tables 4-5, 4-7, and 4-9), indicate the same downstream increases seen in the specific conductance

Table 4-10. Summary Results for the Analysis of Variance (ANOVA) Performed on Basic Water Quality (BWQ) Measurements Collected in the Aquatic Monitoring Program, 1980 to 1983.

| Parameter Measured | Model $r^2$ | Source of Variation: Station DF | Station F Value | Station PR>F | Report Year DF | Report Year F Value | Report Year PR>F | Season DF | Season F Value | Season PR>F |
|---|---|---|---|---|---|---|---|---|---|---|
| **Major Cations** | | | | | | | | | | |
| Calcium | 0.73 | 2 | 23.85** | 0.0001 | 2 | 1.13 | 0.3450 | 2 | 1.56 | 0.2353 |
| Magnesium | 0.86 | 2 | 59.54** | 0.0001 | 2 | 0.05 | 0.9520 | 2 | 3.87* | 0.0390 |
| Sodium | 0.97 | 2 | 344.51** | 0.0001 | 2 | 1.22 | 0.3187 | 2 | 1.67 | 0.2146 |
| Potassium | 0.67 | 2 | 17.36 | 0.0001 | 2 | 0.73 | 0.4956 | 2 | 1.96 | 0.1683 |
| **Major Anions** | | | | | | | | | | |
| Bicarbonate | 0.82 | 2 | 42.00** | 0.0001 | 2 | 0.14 | 0.8707 | 2 | 3.72* | 0.0435 |
| Sulfate | 0.95 | 2 | 195.72** | 0.0001 | 2 | 1.44 | 0.2610 | 2 | 2.18 | 0.1407 |
| Chloride | 0.31 | 2 | 2.58 | 0.1017 | 2 | 0.82 | 0.4575 | 2 | 0.83 | 0.4499 |
| Carbonate | 0.41 | 2 | 2.71 | 0.0925 | 2 | 1.12 | 0.3475 | 2 | 2.69 | 0.0933 |
| **General Parameters** | | | | | | | | | | |
| Total Alkalinity | 0.87 | 2 | 57.84** | 0.0001 | 2 | 0.36 | 0.7003 | 2 | 2.92 | 0.0786 |
| Total Dissolved Solids | 0.95 | 2 | 192.60** | 0.0001 | 2 | 1.40 | 0.2711 | 2 | 3.60* | 0.0472 |
| Total Phosphate | 0.16 | 2 | 1.76 | 0.1986 | 2 | 0.01 | 0.9895 | 2 | 0.00 | 0.9970 |

* Significant at P>0.05
** Significant at P>0.025

summaries presented in Table 4-2. Sodium concentrations are proportional to the salt content of water. Results of the ANOVA, presented in Table 4-10, indicate that no seasonal or report year main effects are evident for the sodium constituent. The Duncan's Multiple Range Test results for sodium indicate complete independence among each of the sampling stations.

Data for the bicarbonate measurements, presented for 1983 in Tables 4-4, 4-6, and 4-8, and for the data base in Tables 4-5, 4-7, and 4-9, also indicate a progressive increase in downstream station concentration. Bicarbonate measurements are directly proportional to measurements of sodium, specific conductance, and sulfates. Table 4-10 shows that bicarbonate exhibits a highly significant station effect, and a marginally significant seasonal effect. The Duncan's Multiple Range Tests for the season and station independent variables indicate a wide variation and overlap in values (Appendix 4-1.4).

Sulfate, like bicarbonate, has a significant station main effect. The station Duncan's Multiple Range Test for sulfate (Appendix 4-1.4) shows that Stations CG-1, YC-1, and YC-2 are unique and independent from each other. This conclusion is confirmed by inspection of the sulfate data presented in the 1983 univariate summaries (Tables 4-4, 4-6, and 4-8).

Three general basic water quality (BWQ) parameters were tested in the ANOVA, and are summarized in Table 4-10. These results indicate that alkalinity and total dissolved solids (TDS) were significant for the station source of variation. TDS measurements also exhibited marginal seasonal significance. As expected, alkalinity and TDS exhibit the same distributional pattern, of increasing concentration downstream from Tract C-a, as do specific conductance, sodium, and bicarbonate (Tables 4-4 to 4-9).

## 4.2 BIOTIC COMPONENTS

### A. Benthic Macroinvertebrates

#### 1. Objectives

Data on benthic macroinvertebrate taxonomic composition, density, and diversity are collected to permit the evaluation of the effects of development activity on these communities. Benthic macroinvertebrates constitute the major component of the secondary trophic level in aquatic ecosystems on and near Tract C-a. Their limited mobility and susceptibility to physical and chemical changes in their environment have been well documented (Kolkowitz and Marsson 1909; Hynes 1960; Tarzwell 1965; Cairns and Dickson 1973; Hart and Fuller 1974; Hilsenhoff 1977; Beck 1977; Hubbard and Peters 1978; Harris and Lawrence 1978; Surdick and Gaufin 1978). Therefore, macroinvertebrates are an important element in the MDP Monitoring Program

#### 2. Methods

The methods utilized to collect and analyze benthic macroinvertebrate samples are described in the RBOSC Scope of Work and are not repeated here (RBOSC 1983).

#### 3. Results and Discussion

Thirty-seven benthic macroinvertebrate taxa were identified from samples collected at three stations in 1983. Count data and species composition for each station are presented in Appendix 4-2.1. Table 4-11 summarizes the species composition and density at each station sampled in 1983. Table 4-12 summarizes the density data by major taxonomic groupings. Diversity, eveness, and richness information are presented for each season and station in Table 4-13.

TABLE 4-11 . MEAN MACROINVERTEBRATE SPECIES DENSITIES SAMPLED IN 1983 ,OVER THREE SEASONS AND THREE STATIONS

| TAXONOMIC NAME | CG-1 | | | YC-1 | | | YC-2 | | |
|---|---|---|---|---|---|---|---|---|---|
| | SPRING | SUMMER | FALL | SPRING | SUMMER | FALL | SPRING | SUMMER | FALL |
| ACARI SPECIES | . | . | . | . | . | . | 38.40 | 12.80 | 172.8 |
| AGABUS SPECIES | . | 6.40 | . | . | . | . | . | . | . |
| ARGIA SPECIES | . | . | . | . | . | . | 19.20 | 0.00 | . |
| BAETIS TRICAUDATUS DODDS | . | . | 172.8 | . | . | 1178 | . | 19.20 | . |
| CALLIBAETIS SPECIES | . | . | . | . | . | . | 6.40 | . | 44.80 |
| FAMILY CAPNIIDAE | . | . | 121.6 | . | . | 25.60 | . | . | . |
| CHELIFERA MACQUART | 6.40 | . | . | 6.40 | . | . | . | . | . |
| CHIRONOMIDAE PUPAE | . | . | 19.20 | . | 550.4 | 108.8 | 44.80 | 6.40 | . |
| TRIBE CHIRONOMINI | . | . | 6.40 | . | . | . | 76.80 | . | 0.00 |
| ORDER COLLEMBOLA | . | . | . | 6.40 | . | . | . | . | . |
| FAMILY CORIXIDAE | . | . | . | . | . | . | . | . | 0.00 |
| TRIBE CORYNONEURINI | . | . | 6.40 | . | . | 19.20 | . | . | . |
| DERONECTES SPECIES | . | . | . | . | . | . | . | . | 0.00 |
| TRIBE DIAMESINI | 12.80 | 108.8 | . | . | 38.40 | . | 6.40 | . | . |
| ENALLAGMA SPECIES | . | . | . | . | . | . | 6.40 | 0.00 | 12.80 |
| EUPARYPHUS SPECIES | . | . | . | . | . | . | 6.40 | . | 6.40 |
| HALIPLUS SPECIES | . | . | . | . | . | . | . | . | 6.40 |
| HAPLOTAXIS GORDIOIDES | 38.40 | . | . | . | . | . | . | . | . |
| HELOBDELLA STAGNALIS | . | . | . | . | 25.60 | 32.00 | 1421 | 6.40 | 204.8 |
| HEXATOMA LATRETILLE | . | . | 6.40 | . | . | . | . | . | . |
| HYALELLA AZTECA SAUSSURE | . | . | . | . | . | 12.80 | 486.4 | 192 | 2080 |
| HYDROPTILA DALMAN | . | . | . | . | . | . | 19.20 | . | . |
| HYDROPSYCHE SPECIES | . | . | . | . | . | . | . | . | 0.00 |
| ISCHNURA SPECIES | . | . | . | . | . | . | . | . | 6.40 |
| LIMNOPHORA ROBINEAU-DESOIDY | . | . | 115.2 | . | . | 288 | . | 0.00 | . |
| LYMNAEA SPECIES | . | . | . | . | . | . | . | 44.80 | 12.80 |
| TRIBE METRIOCNEMINI | 12.80 | 25.60 | 38.40 | 25.60 | 1331 | 544 | 416 | 96.00 | 38.40 |
| NEMOTELUS GEOFFROY | . | . | . | . | . | . | 6.40 | . | . |
| OPTIOSERVUS SPECIES | . | . | . | . | . | . | . | . | 6.40 |
| TRIBE ORTHOCLADIINI | 12.80 | 57.60 | 83.20 | 134.4 | 32.00 | 486.4 | 1824 | 38.40 | 6.40 |
| PALPOMYIA GP. SPECIES MEIGEN | 12.80 | . | . | 6.40 | . | . | 3085 | 70.40 | 6.40 |
| TRIBE PENTANEURINI | . | . | . | . | . | 25.60 | 6.40 | 0.00 | 0.00 |
| PROTOPTILA ROSS | . | . | 6.40 | . | . | . | . | . | . |
| SIMULIUM SPECIES | . | . | 96.00 | . | . | 800 | 870.4 | 678.4 | 12.80 |
| TABANUS SPECIES | . | . | . | . | . | . | 25.60 | . | . |
| TRIBE TANYTARSINI | . | . | 19.20 | 25.60 | . | 0.00 | 1664 | 0.00 | 19.20 |
| FAMILY TUBIFICIDAE | 70.40 | 6.40 | 1312 | 19.20 | 51.20 | 2093 | 5120 | 128 | 160 |

TABLE 4-12 . MAJOR BENTHIC MACROINVERTEBRATE TAXONOMIC GROUPING MEAN DENSITIES (NO./M2) COLLECTED IN 1983

| MAJOR TAXONOMIC GROUP | CG-1 | | | YC-1 | | | YC-2 | | |
|---|---|---|---|---|---|---|---|---|---|
| | SPRING | SUMMER | FALL | SPRING | SUMMER | FALL | SPRING | SUMMER | FALL |
| CLASS OLIGOCHAETA | 70.40 | 6.40 | 1312 | 19.20 | 51.20 | 209E3 | 5120 | 128 | 160 |
| ORDER EPHEMEROPTERA | . | . | 172.8 | . | . | 1178 | 6.40 | 19.20 | 44.80 |
| ORDER ODONATA | . | . | . | . | . | . | 6.40 | 0.00 | 12.80 |
| ORDER PLECOPTERA | . | . | 121.6 | . | . | 25.60 | . | . | . |
| ORDER COLEOPTERA | . | . | . | 6.40 | 25.60 | 32.00 | 1421 | 6.40 | 54.40 |
| ORDER TRICOPTERA | 38.40 | . | 6.40 | . | . | . | 22.40 | . | 0.00 |
| FAMILY CHIRONOMIDAE | 12.80 | 64.00 | 28.80 | 61.87 | 488 | 197.3 | 363 | 28.16 | 12.80 |
| PHYLUM ARTHROPODA | 9.60 | 6.40 | 72.53 | 6.40 | . | 366.9 | 644.6 | 142.6 | 287.2 |

Table 4-13. Comparison of Diversity Indices of Benthic Macroinvertebrates During RBOSC MDP Studies (1978-1983).

| Station | Season | Index | YEAR 1978 | 1979 | 1980 | 1981 | 1982 | 1983 |
|---|---|---|---|---|---|---|---|---|
| CG-1 | Spring | Diversity | 2.47 | 2.06 | 1.51 | 1.71 | 1.95 | 1.35 |
| | | Evenness | 0.92 | 0.94 | 0.78 | 0.74 | 0.20 | 0.22 |
| | | Richness | 7 | 9 | 7 | 10 | 9 | 7 |
| | Summer | Diversity | 0.86 | 1.02 | 0.85 | 1.24 | 2.00 | 1.84 |
| | | Evenness | 0.67 | 0.57 | 0.37 | 0.90 | 0.14 | 0.88 |
| | | Richness | 2 | 6 | 10 | 4 | 22 | 5 |
| | Fall | Diversity | 0.96 | 1.47 | 1.85 | 1.28 | 1.95 | 1.82 |
| | | Evenness | 0.35 | 0.64 | 0.80 | 0.62 | 0.18 | 0.73 |
| | | Richness | 8 | 10 | 8 | 8 | 12 | 13 |
| YC-1 | Spring | Diversity | | | | 2.06 | 1.18 | 1.62 |
| | | Evenness | | | | 0.76 | 0.10 | 0.54 |
| | | Richness | | | | 15 | 13 | 7 |
| | Summer | Diversity | | | | 1.33 | | 1.02 |
| | | Evenness | | | | 0.96 | | 0.35 |
| | | Richness | | | | 4 | | 6 |
| | Fall | Diversity | | | | 0.92 | 1.68 | 1.73 |
| | | Evenness | | | | 0.32 | 0.15 | 0.21 |
| | | Richness | | | | 17 | 13 | 13 |
| YC-2 | Spring | Diversity | | | | 1.47 | 1.57 | 1.63 |
| | | Evenness | | | | 0.56 | 0.12 | 0.25 |
| | | Richness | | | | 14 | 22 | 20 |
| | Summer | Diversity | | | | 0.96 | 1.94 | 1.88 |
| | | Evenness | | | | 0.37 | 0.15 | 0.22 |
| | | Richness | | | | 13 | 21 | 16 |
| | Fall | Diversity | | | | 1.29 | 0.83 | 1.22 |
| | | Evenness | | | | 0.45 | 0.06 | 0.13 |
| | | Richness | | | | 18 | 16 | 21 |

The benthic macroinvertebrate community structure in the Yellow Creek drainage system appears to be influenced primarily by water temperature, dissolved oxygen and the occasional dry stream bed conditions. Most of the species listed in Table 4-11 are able to tolerate a wide range of conductivity, such as that observed in the Corral Gulch-Yellow Creek drainage. Velocity and turbidity have been demonstrated to influence the community structure of macroinvertebrates in spring runoff and summer low water conditions (Pennak 1974; Wilber 1974). Simulium (Diptera:Simuliidae) species was the only taxon observed at each station and during each season in 1983 (Table 4-11). Simuliids tend to inhabit streams with constant and uninterrupted flow conditions (Merritt and Cummins 1978). The habitat conditions were relatively stable in 1983, with increased precipitation and continuous flow throughout the entire summer season. It should be noted, however, that 1983 was an exceptionally wet year.

Benthic macroinvertebrate density data (No./$m^3$) were evaluated for a normal distribution. These data required log transformation to meet the required assumption of normal distribution. Results of the two different ANOVA techniques are summarized in Tables 4-14 and 4-15. The two-way ANOVA, by individual stations, indicated a significant interaction over time for Station YC-1 (report year x season interaction: Table 4-14).

Results from the three-way ANOVA, without interaction, for a selected set of higher level taxonomic groupings are presented in Table 4-15. The Phylum Nematoda was purposely left out of this analysis because of the small data set that exists for this major taxon. This analysis is very specific in that each of the taxa listed is subjected to the rigorous assumptions outlined for ANOVA. This model was run without interaction to evaluate the independent behavior of each main effect for each of the taxa listed. Of the taxa listed, only the Class Oligochaeta and the Family Chironomidae exhibited significant main effects. Density estimates grouped into the

Table 4-14. Summary Analysis of Variance Statistics for Log Transformed Benthic Macroinvertebrate Density Data for each Station Sampled.

| Station | Model | Source of Variation | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Report Year | | | Season | | | Report Year * Season | | |
| Density | $r^2$ | DF | F Value | PR>F | DF | F Value | PR>F | DF | F Value | PR>F |
| CG-1 Density | 0.13 | 4 | 1.97 | 0.1014 | 2 | 2.93 | 0.0563 | 8 | 0.87 | 0.5399 |
| YC-1 Density | 0.25 | 2 | 2.31 | 0.1065 | 2 | 0.51 | 0.6018 | 3 | 6.15** | 0.0010 |
| YC-2 Density | 0.21 | 2 | 0.11 | 0.8943 | 2 | 0.37 | 0.6903 | 4 | 0.50 | 0.7386 |

* Significant at P>0.05
** Significant at P>0.025

Table 4-15. Summary Analysis of Variance Statistics for Log Transformed Benthic Macroinvertebrate Data, by Major Taxonomic groupings.

| Major Taxa Density | Model $r^2$ | Source of Variation: Report Year DF | Report Year F Value | Report Year PR>F | Season DF | Season F Value | Season PR>F | Station DF | Station F Value | Station PR>F |
|---|---|---|---|---|---|---|---|---|---|---|
| Class Oligochaeta Density | 0.88 | 4 | 7.24** | 0.0022 | 2 | 1.27 | 0.3122 | 2 | 13.09** | 0.0006 |
| Order Ephemeroptera Density | 0.70 | 4 | 0.24 | 0.9095 | 2 | 2.57 | 0.1308 | 2 | 0.63 | 0.5523 |
| Order Odonata Density | 0.60 | 2 | 1.80 | 0.2436 | 2 | 0.03 | 0.9715 | 1 | 0.43 | 0.5364 |
| Order Coleoptera Density | 0.46 | 4 | 0.55 | 0.7066 | 2 | 0.24 | 0.7928 | 2 | 0.35 | 0.7113 |
| Order Tricoptera Density | 0.63 | 2 | 1.50 | 0.2965 | 2 | 0.70 | 0.5338 | 2 | 0.21 | 0.8149 |
| Family Chironomidae Density | 0.49 | 4 | 7.29** | 0.0001 | 2 | 1.97 | 0.1444 | 2 | 11.01** | 0.0001 |
| Phylum Arthorpoda Density | 0.24 | 4 | 0.15 | 0.9619 | 2 | 0.29 | 0.7513 | 2 | 3.97* | 0.0227 |

* Significant at P>0.05
** Significant at P>0.025

Class Oligochaeta exhibited significant report year and station sources of variation. Most members of this class are euryhaline and can also tolerate significant changes in flow in a stream environment; thus, it is difficult to determine why members of this group vary over years and stations. Differences in the depth of bottom sediment and silt substrate can effect the count data collected. The Duncan's Multiple Range test results for this group indicated that station YC-2 had a significantly higher density of the Oligochaeta than all other stations (Appendix 4-2.3). Station YC-2 has a silt bottom with a large amount of fine material, which may be a better habitat for members of this class. This test further indicated complete independence among the stations.

The Chironomidae showed a significant change over years and stations (Table 4-15). This group is both diverse in composition and exhibits a wide variation in calculated densities (RBOSC 1982). The Duncan's Multiple Range Test results for the Chironomidae indicate that station CG-1 has a significantly lower density than the other two stations (Appendix 4-2.3). Differences in the physical conditions outlined in Section 4.1 of this report may help to explain this significance.

Species composition and diversity are discussed below for each station.

a. Station CG-1 - In 1983, the mean benthic macroinvertebrate densities were greater than those recorded for the major taxa in 1979 and 1981 and less than those density data recorded for 1982 (RBOSC 1982). Members of the Phylum Arthropoda exhibited the widest variation in density data over years and seasons at station CG-1: the highest density was recorded in the fall of 1980 (RBOSC 1982) while 1983 densities were substantially lower for the summer and spring seasons (Table 4-12). In the 1983 spring sampling season, members of the family Tubificidae were dominant at station CG-1; the Tribe Diamesini dominated the summer season, while Baetis tricaudatus (Baetidae) was dominant in the fall season (Table 4-11). All of these organisms have a high fecundity rate and short life cycle, characteristics that are perhaps largely responsible for their dominance at

a station subjected to fluctuations in environmental conditions from two different feeder drainages. Over the entire MDP sampling program (1978-1983), the Ephemeroptera have consistently been the dominant higher level taxanomic group. In 1983 the Oligochaeta dominated each season and station (RBOSC 1982).

Station CG-1 had consistently lower diversity indices in 1983 than for 1982 (Table 4-13). Species richness and diversity were higher in the summer season of 1982 than any other MDP sampling season at station CG-1. Diversity indices are used to reflect gross changes in the species population and community structure. Over time and season, diversity indices at station CG-1 have been variable. Changes in these indices during the summer sampling season may be somewhat reflective of the survival of macroinvertebrates in the harsh spring runoff conditions that are at times seen at this station.

b. Station YC-1 - In 1983, the mean benthic macroinvertebrate densities were generally lower than most of the major taxa reported in 1982 (RBOSC 1982). The Oligochaeta exhibited the greatest density change at this station between years and seasons sampled (Table 4-12). Spring species composition was dominated by the Orthocladiini (Table 4-11). The fall season was dominated by the Tubificidae.

Diversity indices at station YC-1 were higher in the spring of 1983 than those reported for the 1982 spring season (Table 4-13). Species richness was lower in the spring of 1983 than reported for 1982. There was no fall difference in the species richness at this site for 1982 and 1983 data; however, diversity and evenness were greater in the fall of 1983. This suggests that the benthic community recovered to a healthy population after the dry conditions seen at this station in 1982, and that a relatively stable flow regime may exist in this part of Yellow Creek when water is present.

c. Station YC-2 - Mean benthic invertebrate densities were lower in all seasons for data collected in 1983 when compared to data reported for the same seasons in 1982 (RBOSC 1982). Arthropods dominated the fall season; the spring and summer seasons were dominated by the Oligochaeta (Table 4-12). The benthic faunal community at Station YC-2 is different from the two upstream sites (Stations CG-1 and YC-1). A coexistence is evident for the Oligochaetes (Tubificidae) and Simuliidae in the spring 1983. Tubificidae, Talitridae (Hyalella species), and Simulium species were dominant in the summer of 1983, and the Talitridae (Hyalella azteca) dominated the fall samples.

Data on Table 4-13 indicate that the diversity and richness indices were greater in the fall of 1983 than reported for the same season in 1982 at station YC-2. Species diversity remained essentially the same for the spring and summer seasons, while species evenness appeared to increase (Tables 4-11 and 4-13).

## 4.3 SUMMARY

Physical parameters examined at each of the aquatic sampling stations indicate seasonal as well as annual variability. A natural variation trend of increased downstream conductivity measurements was identified in 1982 and confirmed in 1983.

Selected water quality measurements made in 1983 and throughout the MDP program indicate a natural variation trend in increasing concentration with distance downstream from Tract C-a. Sodium, bicarbonate, total dissolved solids and alkalinity each were demonstrated, statistically, to be good indicators of water quality differences among the stations sampled.

Benthic macroinvertebrate data sampled at three locations in 1983 can be classified into two cohorts based upon density data. The first cohort consists of stations CG-1 and YC-1: streams with benthic fauna which appear to be affected by variable water quality and velocity conditions. The second cohort includes the lower Yellow Creek Station, YC-2: a hydrologically more stable system, stressed primarily by naturally occurring water quality conditions. The macroinvertebrate communities at Stations CG-1 and YC-1 seem to show seasonal changes associated with spring runoff, while the macroinvertebrate communities at Station YC-2 do not seem to be affected by spring runoff. Benthic macroinvertebrate samples from all three of these sites are, basically, similar in taxonomic composition; that is, they all had relatively low diversity values. This is characteristic of small, turbid streams in the semiarid West, where relatively silty substrates, high total dissolved solids and appreciable fluctuations in velocity are commonly found.

No activities associated with the Tract C-a lease appear to have influenced the aquatic ecosystem on Corral Gulch-Yellow Creek. RBOSC is maintaining a zero discharge National Pollutant Discharge Elimination System (NPDES) permit and has not released treated sewage or mine water in 1983. All changes noted should be attributed to natural variability in the system.

## LITERATURE CITED


Beck, W.M., Jr. 1977. Environmental requirements and pollution tolerance of common freshwater Chironomidae. U.S. Environmental Protection Agency. Environmental Monitoring Series EPA-600/4-77-024. 261 pp.

Cairns, J., Jr. and K.L. Dickson (eds.). 1973. Biological methods for the assessment of water quality. Am. Soc. for Testing and Materials Special Technical Publication S28:1-256.

Harris, T.L. and T.M. Lawrence. 1978. Environmental requirements and pollution tolerance of Trichoptera. U.S. Environmental Protection Agency. Environmental Monitoring Series EPA 600/4-78-063. 310 pp.

Hart, C.W., Jr. and S.L.H. Fuller (eds.). 1974. Pollution ecology of freshwater invertebrates. Academic Press, N.Y. 389 pp.

Hilsenhoff, W.L. 1977. Use of arthropods to evaluate water quality in streams. Wisc. Dept. of Nat. Res. Tech. Bull. No. 100. Madison. 15 pp.

Hubbard, M.D. and W.L. Peters. 1978. Environmental requirements and pollution tolerance of Ephemeroptera. U.S. Environmental Protection Agency. Environmental Monitoring Series EPA-600/4-78-061. 461 pp.

Hutchinson, G.E. 1975. A treatise on limnology. III. Limnological botany. John Wiley and Sons, Inc., N.Y. 660 pp.

Hynes, H.B.N. 1960. The biology of polluted waters. Liverpool Univ. Press, Liverpool. 202 pp.

Kolkowitz, R. and M. Marsson. 1909. Ecology of animal saprobia. Int. Rev. Hydrobiology and Hydrogeography. 2:126-153.

Merritt, R.W. and K.W. Cummins. 1978. An introduction to the aquatic insects of North America. Kendall/Hunt Publishing Co. 441 pp.

Pennak, R.W. 1974. Limnological status of streams, Piceance Creek Basin, Rio Blanco and Garfield Counties, Colo. Ross-23, prepared for the State of Colorado. Thorne Ecological Institute, Boulder, Colorado.

Rio Blanco Oil Shale Company. 1982. Modular Development Phase Monitoring Report 9, January 1981 - December 1981. Gulf Oil Corp. and Standard Oil Co. (Indiana).

Rio Blanco Oil Shale Company. 1983. Modular development phase monitoring program scope of work. Revision 7.0. Gulf Oil Corporation and Standard Oil Co. (Indiana).

Surdick, R.F. and A.R. Gaufin. 1978. Environmental requirements and pollution tolerance of Plecoptera. U.S. Environmental Protection Agency. Environmental Monitoring Series EPA-600/4-78-062. 417 pp.

Tarzwell, C.M. (ed.). 1965. Biological problems in water pollution: third seminar 1962. U.S. Public Health Service. Division of Water Supply and Pollution Control. Cincinnati. 424 pp.

Ward, J.V. and R.G. Dufford. 1979. Longitudinal and seasonal distribution of macroinvertebrates and epilithic algae in a Colorado springbrook-pond system. Arch. Hydrobiol. 86(3):284-321.

# SECTION 5
# HYDROLOGY STUDIES

## 5.0 INTRODUCTION

During 1983, the hydrology monitoring program was conducted in accordance with the lease suspension period Scope of Work, Revision 7.0 (RBOSC 1983a). This program focused on three elements:

1. Dewatering/Reinjection/Discharge System
2. MIS Modular Development Area
3. Retort and Mine Water Systems

Data on surface water, ground water, and developmental activities (e.g. retort water) monitoring are included in this section. Surface monitoring includes U.S.G.S. gaging stations, flumes, and springs and seeps, all on or near Tract C-a. Ground water data were collected from alluvial, and upper and lower aquifer monitor wells.

The development activities monitoring program includes sampling of dewatering and reinjection operations on Tract C-a.

Retort and mine water systems include the waters contaminated by the in situ retorts and water inflow to the mine.

Data analyses and summaries are reported along with raw data found in Appendix 5. Supplemental data on retort and mine water systems have been previously reported to the OSPO and are not duplicated here.

The hydrology monitoring stations have been classified as follows:

- Type I (Control) stations not expected to be influenced by a given set of development activities.

- Type II (Near-field) stations expected to detect direct, relatively short-term impacts, should impacts result from development; such stations are located generally close to and downgradient from development activities or operations.

- Type III (Far-field) stations expected to detect indirect or long-term impacts, should impacts result from development; such stations are generally located downgradient and relatively distant from development areas.

This grouping of monitoring stations allows for spatial and temporal comparisons of water quality and physical characteristics. Thus, baseline data (collected since 1974) can be compared to post-operational data, and control areas can be compared to potentially impacted areas.

## 5.1 DEWATERING/REINJECTION/DISCHARGE PROGRAM

### 1. Objectives

The objectives of this program are to monitor the operation of the dewatering/reinjection system, and to measure the effects on surface and ground water systems.

### 2. Methods

The upper aquifer near the MIS area was dewatered during mining/retorting activities, and dewatering has been continued during suspension operations to keep the burned retorts from flooding completely and interacting with aquifers. This system maintains the cone of depression, reinjecting water down gradient from the MIS area at various points. The potential effects on ground water from operation of this system are changes in water levels snd/or surface flows. Field water quality parameters (pH, specific conductance, and temperature) are also sampled along with water chemistry at selected sites. Sampling methods, locations, and schedules are described in previous MDP Monitoring Report Seven and the Scope of Work (RBOSC 1981, 1983a). Stations included in the dewatering/reinjection/discharge monitoring program are as follows:

| Station Class | Station Identification | |
|---|---|---|
| Type I Control | Springs and Seeps | |
| | SPG-3 | SPG-5 |
| | SPG-4 | SPG-MILL |
| | Deep Aquifer | |
| | GS-M9U | AM-3U |
| | GS-M10U | GS-9U |
| | GS-M12U | |
| | CE-708U | |

| Station Class | Station Identification |
|---|---|
| Type II<br>Near Field | Mine Seepage<br><br>Mine water and sour water sumps<br>Composite reinjection<br><br>Discharge Sites/Streams<br><br>YFLDIS<br><br>Deep Aquifer<br><br>GS-D1U GS-D6U<br>GS-D3U GS-D8U<br>GS-MDP2CU CE-702U |
| Type II<br>Far Field | YLDGEDGE - leading edge<br><br>Deep Aquifer<br><br>GS-M3U<br>CE-709U<br>GS-17L |

## 3. Results and Discussion

The monitoring data have been examined for temporal and spatial variations. Temporal changes were examined by comparing 1983 univariate statistics (e.g., mean and maximum values) with similar statistics for previous years. The major focus of these evaluations was on comparison of 1982 and 1983 data sets, although longer term changes and trends were also examined.

Extensive repetition of previously reported (pre-1983) data has been avoided. The 1982 data base is provided in MDP Monitoring Report 11 (RBOSC 1983b). Spatial changes were examined by comparison of univariate statistics for upper aquifer wells divided into control, near-field, and far-field station groups. In addition, a multivariate analysis of variance (MANOVA) procedure

was used to test the significance of temporal and spatial variability and space-time interactions.

Unless noted otherwise, the parameters discussed and listed in this section and associated appendices have the following units: water chemistry constituents, milligrams per liter; mercury, micrograms per liter; pH, standard units; conductivity (specific conductance or ec), micromhos per cm; temperature, degress Celsius.

A. Dewatering/Reinjection System

During the majority of 1983, dewatering was accomplished using mine sumps. In October two dewatering wells, GS-D1U and GS-D5U, were added to the system. Modifications of the cone of depression resulted from this, with all of the 1983 contour lines (Figure 5-1) diminishing relative to 1982 (Figure 5-2) indicating a significant filling of the cone of depression.

Total mine water production increased from a low of 762 gpm in early January to the 900-1100 gpm range from mid-January through late June. Production then rose steadily until it peaked at 1748 gpm in mid-August. Mine water flows remained high, in the 1600-1700 gpm range, until late October when the additional two dewatering wells were activated. Mine water production then varied from 1350-1500 gpm until the end of 1983. The dewatering flows were entirely reinjected or consumed during 1983, resulting in no surface discharge.

Field measurements of mine water collected from the composite reinjection water (YCOINJ) and the Jeffrey Pond (YJEFFPOND) are shown in Appendix 5-1.2. The Jeffrey Pond conductivity varied from 1300-1600 micromhos per cm with a mean of 1452. These results are similar to 1982 data for the Jeffrey Pond. The pH ranged from 7.3 to 8.0 with a mean of 7.6, which was lower than the 1982 mean.

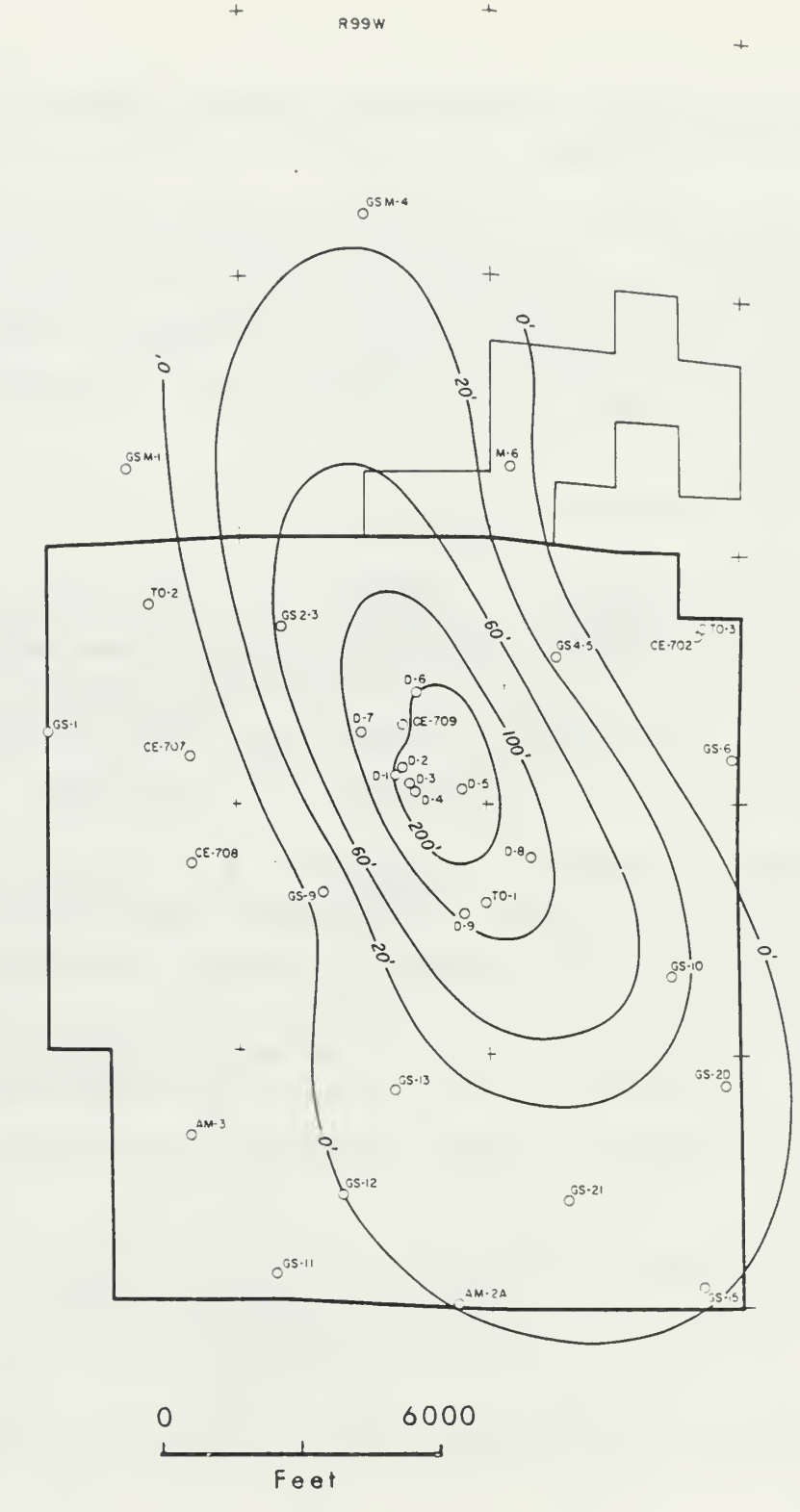



Figure 5-1. Upper Aquifer Cone of Depression September, 1983.

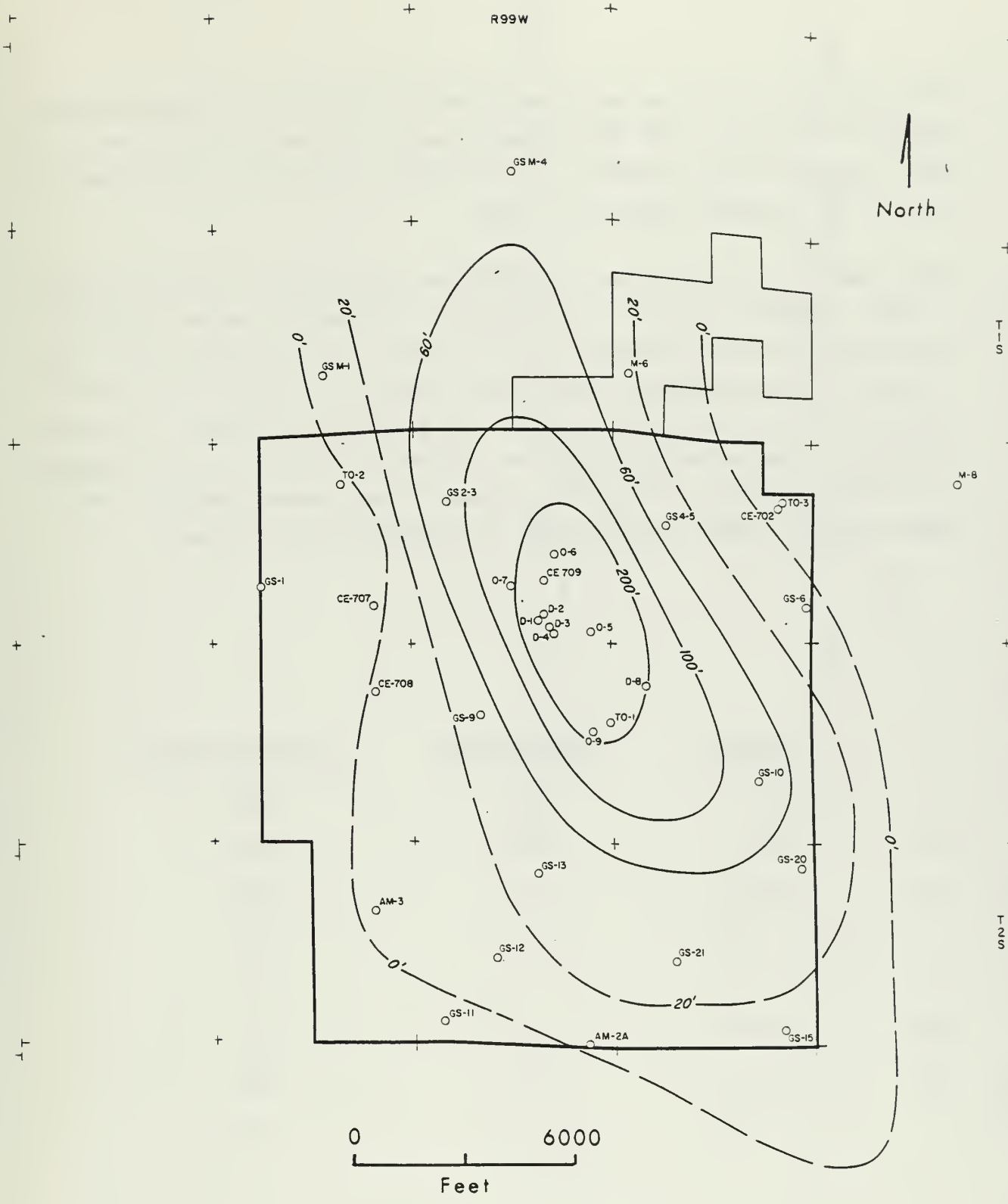



Figure 5-2. Upper Aquifer Cone of Depression October, 1982

The composite reinjection water exhibited conductivity (field measurement) readings ranging from 1350-1900 micromhos per cm (Figure 5-3) with a mean of 1486, similar to the 1982 mean. The pH values varied from 7.0 to 8.2 with a mean of 7.8, slightly lower than in 1982.

Water chemistry for YCOINJ and YJEFFPOND was comparable to values exhibited in 1982 (Appendix 5-1.1). The composite reinjection water showed an increase in carbonate and DOC, while the Jeffrey Pond water exhibited slight increases in bicarbonate and sulfate, and a decrease in carbonate. Overall, observations for the mine water were stable throughout the year. Composite reinjection time series plots for the 1983 pH and conductivity measurements are shown in Figures 5-3 and 5-4. Means of major water chemistry constituents exceeding means from 1980-1983 for YJEFFPOND are as follows:

| | 1983 Mean | 1980-1983 Mean | 1980-1983 Maximum |
|---|---|---|---|
| ec | 1462 | 1412 | 1600 |
| TDS | 1087 | 1026 | 1056 |
| Alk | 496 | 472 | 498 |
| Ca | 50 | 42 | 80 |
| Mg | 83 | 78 | 97 |
| $HCO_3$ | 571 | 547 | 587 |
| $SO_4$ | 404 | 376 | 494 |
| B | .26 | .20 | .30 |

Figure 5-3. Conductivity (micromhos per cm) of Composite Reinjection, YCOINJ, 1983.

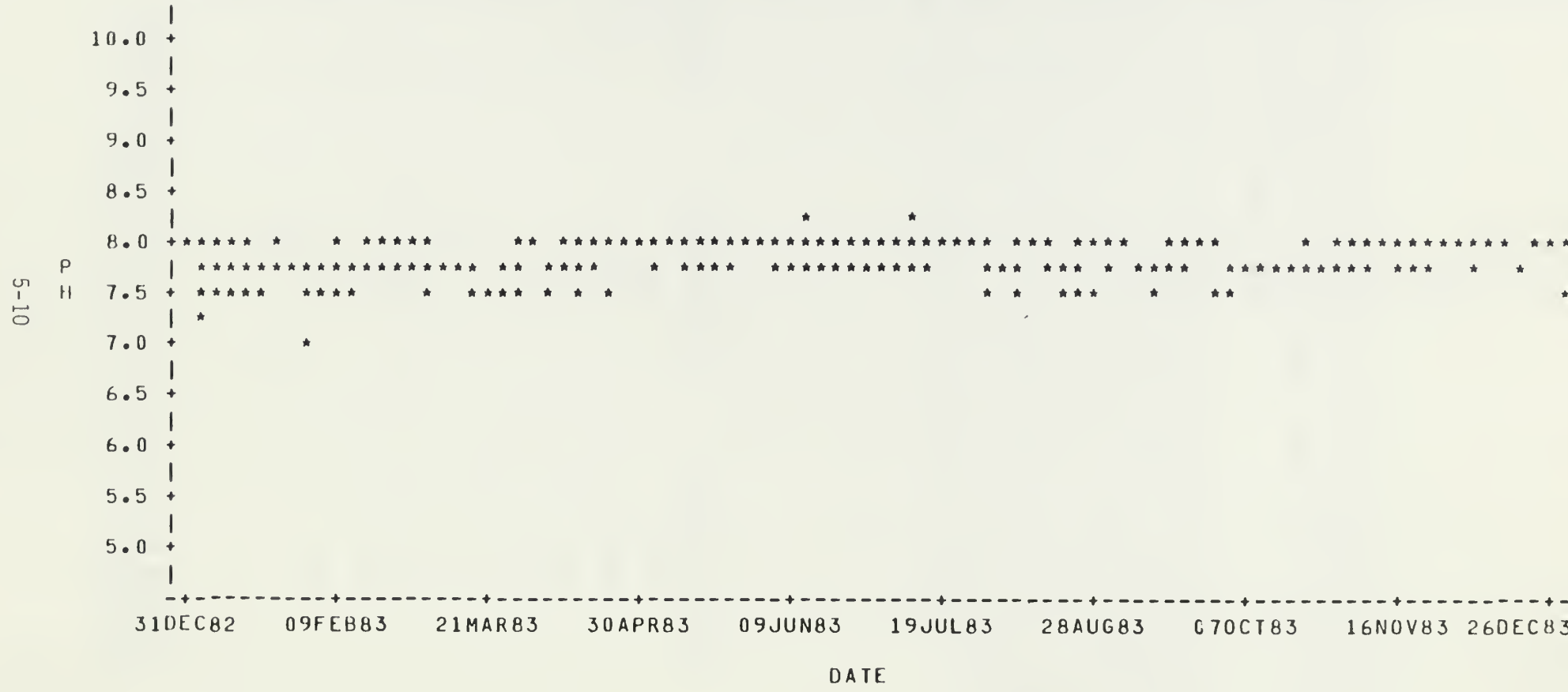



Figure 5-4. Composite Reinjection ph (S.U.), 1983.

B. Springs/Seeps and Leading Edge

The 1983 field measurements collected at control spring stations are summarized in Table 5-1. Springs and seeps data are presented in Appendix 5-1.2. The 1983 values were not significantly different than previous years, with the exception of flows in SPG-3 and SPG-4. Site SPG-3 set a new maximum flow of 125 gpm in July after heavy runoff and precipitation. In Corral Gulch, SPG-4 was buried in a mud slide, showing no flow in July, but resurfacing by October.

The leading edge (the maximum extent of downstream surface flow in Yellow Creek from the County Road 24 crossing) extended to the White River (20 miles) in July, due to heavy run-off and precipitation during the spring. In comparison, the farthest distance of the edge during 1982 was 2.5 miles. Leading edge (YLDGEDGE) data are presented in Appendix 5-1.2.

C. Upper Aquifer

1. Field Data - Data collected during 1983 are presented in Appendix 5-1.3. Summaries of these field data for control, near-field, and far-field station groups are presented in Table 5-2. Means for control and near-field water levels (depth to water) show decreased water levels compared to the 1982 means. These means, however, cannot accurately be compared to the 1982 data, because of changes in the monitoring locations and schedules made during 1983. Mean water levels, in actuality, were higher in all three areas during 1983 than those for 1982, when compared on an individual station basis. All water levels rose appreciably in late spring due to heavy snow-melt and precipitation, and remained elevated for the remainder of 1983.

Mean conductivity and pH values were essentially the same for control sites for 1983 and 1982. The mean near-field pH was 7.2 in 1983, compared to 8.1 in 1982, while the mean conductivity remained stable in these wells. Groundwater pH in the far-field wells showed no appreciable change between 1983

Table 5-1. Summary of Field Data for Springs and Seeps, Dewatering/Reinjection/Discharge Program, 1983.

TYPE=SPRINGS AND SEEPS AREA=CONTROL REPORT YEAR=1983

| PARAMETER | N | MEAN | STD | MAX | MIN | P5 | P95 |
|---|---|---|---|---|---|---|---|
| DEPTH | 0 | . | . | . | . | . | . |
| PH | 14 | 7.78 | 0.46 | 8.60 | 7.10 | 7.10 | 8.60 |
| CONDUCTIVITY | 14 | 1403.57 | 210.74 | 1700.00 | 1100.00 | 1100.00 | 1700.00 |
| TEMPERATURE | 14 | 12.36 | 7.34 | 26.20 | 3.50 | 3.50 | 26.20 |
| FLOW | 9 | 28.44 | 38.55 | 125.00 | 0.00 | 0.00 | 125.00 |
| TOT SUS SOLIDS | 0 | . | . | . | . | . | . |
| PRESSURE | 0 | . | . | . | . | . | . |

Table 5-2. Summary of Field Data from Upper Aquifer Wells, Dewatering/Reinjection/Discharge Program, 1983.

TYPE=UPPER AQUIFER AREA=CONTROL REPORT YEAR=1983

| PARAMETER | N | MEAN | STD | MAX | MIN | P5 | P95 |
|---|---|---|---|---|---|---|---|
| WATER LEVEL | 32 | 210.01 | 165.58 | 433.00 | 22.60 | 24.29 | 432.67 |
| TEMPERATURE | 13 | 11.32 | 1.62 | 13.70 | 8.70 | 8.70 | 13.70 |
| CONDUCTIVITY | 13 | 1234.62 | 178.40 | 1500.00 | 950.00 | 950.00 | 1500.00 |
| PH | 13 | 7.49 | 0.35 | 8.00 | 7.00 | 7.00 | 8.00 |

TYPE=UPPER AQUIFER AREA=NEAR FIELD REPORT YEAR=1983

| PARAMETER | N | MEAN | STD | MAX | MIN | P5 | P95 |
|---|---|---|---|---|---|---|---|
| WATER LEVEL | 170 | 532.79 | 119.88 | 632.10 | 165.90 | 209.47 | 622.09 |
| TEMPERATURE | 12 | 14.58 | 1.28 | 16.00 | 11.40 | 11.40 | 16.00 |
| CONDUCTIVITY | 12 | 1543.75 | 275.13 | 2200.00 | 1200.00 | 1200.00 | 2200.00 |
| PH | 12 | 7.29 | 0.29 | 7.70 | 6.90 | 6.90 | 7.70 |

TYPE=UPPER AQUIFER AREA=FAR FIELD REPORT YEAR=1983

| PARAMETER | N | MEAN | STD | MAX | MIN | P5 | P95 |
|---|---|---|---|---|---|---|---|
| WATER LEVEL | 122 | 153.57 | 123.94 | 533.50 | 11.20 | 23.71 | 354.14 |
| TEMPERATURE | 13 | 11.42 | 2.38 | 14.70 | 7.70 | 7.70 | 14.70 |
| CONDUCTIVITY | 13 | 1492.31 | 356.98 | 2600.00 | 1200.00 | 1200.00 | 2600.00 |
| PH | 13 | 7.92 | 1.11 | 9.60 | 6.80 | 6.80 | 9.60 |

and 1982, while the mean conductivity dropped from 1651 micromhos per cm in 1982 to 1400 micromhos per cm in 1983, possibly reflecting recharge. Temperature data in 1983 was consistent with the 1982 data.

The 1983 summaries shown in Table 5-2 illustrate spatial gradients in the upper aquifer. As expected, mean depth to water is greater in the near-field area due to dewatering operations. As observed in previous years, groundwater temperature is greater in the near-field area relative to the surrounding areas and conductivity was highest, while the pH was lowest, in the near-field area, although the changes between areas were not great.

2. Water Chemistry Data - Results of water chemistry analysis of upper aquifer samples in the 1983 dewatering/reinjection/discharge program are summarized in Tables 5-3, 5-4 and 5-5. Upper aquifer chemistry data are presented in Appendix 5-1.1. Water chemistry observations for 1983 in the upper aquifer control wells were generally similar to concentrations observed in 1982. Major water chemistry parameters in the control well area that exceeded 1982 means are listed below:

| | 1983 Means | 1982 Means |
|---|---|---|
| sodium | 156 | 154 |
| fluoride | .90 | .49 |
| ammonia | .54 | .50 |
| boron | .23 | .20 |

The only major parameter value exceeding the 1982 maximum value was fluoride, with an observation of 1.10 mg/l in 1983 compared to the 1982 maximum value of .97 mg/l. These changes were insignificant.

Table 5-3. Summary of Water Chemistry Data for Upper Aquifer Control Wells, Dewatering/Reinjection/ Discharge Program, 1983.

TYPE=UPPER AQUIFER AREA=CONTROL REPORT YEAR=1983

BASIC AND TRACE WATER QUALITY CONSTITUENTS

| PARAMETER | N | MEAN | STD | MAX | MIN | P5 | P95 |
|---|---|---|---|---|---|---|---|
| PH | 4 | 7.65 | 0.40 | 8.00 | 7.30 | 7.30 | 8.00 |
| CONDUCTIVITY | 4 | 1350.00 | 362.86 | 1850.00 | 1000.00 | 1000.00 | 1850.00 |
| TOT DIS SOLIDS | 4 | 1127.25 | 381.22 | 1672.00 | 790.00 | 790.00 | 1672.00 |
| ALKALINITY | 4 | 419.00 | 59.35 | 494.00 | 357.00 | 357.00 | 494.00 |
| CALCIUM | 4 | 61.75 | 20.47 | 88.00 | 38.00 | 38.00 | 88.00 |
| MAGNESIUM | 4 | 81.50 | 37.29 | 130.00 | 40.00 | 40.00 | 130.00 |
| POTASSIUM | 4 | 0.57 | 0.22 | 0.79 | 0.34 | 0.34 | 0.79 |
| SODIUM | 4 | 180.00 | 53.54 | 250.00 | 120.00 | 120.00 | 250.00 |
| BICARBONATE | 4 | 491.50 | 69.61 | 578.00 | 418.00 | 418.00 | 578.00 |
| CARBONATE | 4 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| CHLORIDE | 4 | 4.07 | 4.52 | 9.00 | 0.11 | 0.11 | 9.00 |
| NITRATE | 4 | 0.10 | 0.00 | 0.10 | 0.10 | 0.10 | 0.10 |
| SULFATE | 4 | 450.75 | 222.69 | 770.00 | 252.00 | 252.00 | 770.00 |
| FLUORIDE | 4 | 0.82 | 0.26 | 1.10 | 0.60 | 0.60 | 1.10 |
| AMMONIA | 4 | 0.46 | 0.44 | 1.11 | 0.19 | 0.19 | 1.11 |
| PHOSPHATE | 4 | 0.01 | 0.00 | 0.02 | 0.01 | 0.01 | 0.02 |
| BORON | 4 | 0.26 | 0.07 | 0.37 | 0.21 | 0.21 | 0.37 |
| SILICA | 4 | 26.50 | 8.10 | 35.00 | 16.00 | 16.00 | 35.00 |
| IRON | 0 | . | . | . | . | . | . |
| DIS ORG CARBON | 4 | 5.00 | 1.41 | 7.00 | 4.00 | 4.00 | 7.00 |
| ARSENIC | 4 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| SELENIUM | 4 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| VANADIUM | 4 | 0.10 | 0.00 | 0.10 | 0.10 | 0.10 | 0.10 |
| MOLYBDENUM | 4 | 0.10 | 0.00 | 0.10 | 0.10 | 0.10 | 0.10 |
| MERCURY | 4 | 0.30 | 0.00 | 0.30 | 0.30 | 0.30 | 0.30 |
| ALUMINUM | 4 | 0.10 | 0.00 | 0.10 | 0.10 | 0.10 | 0.10 |
| BARIUM | 4 | 0.10 | 0.00 | 0.10 | 0.10 | 0.10 | 0.10 |
| BERYLLIUM | 4 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| BISMUTH | 4 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| BROMIDE | 4 | 0.15 | 0.10 | 0.30 | 0.10 | 0.10 | 0.30 |
| CADMIUM | 4 | 1.25 | 0.50 | 2.00 | 1.00 | 1.00 | 2.00 |
| CHROMIUM | 4 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| COPPER | 4 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| GALLIUM | 4 | 0.50 | 0.00 | 0.50 | 0.50 | 0.50 | 0.50 |
| GERMANIUM | 4 | 0.10 | 0.00 | 0.10 | 0.10 | 0.10 | 0.10 |
| LEAD | 4 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| LITHIUM | 4 | 0.11 | 0.07 | 0.19 | 0.05 | 0.05 | 0.19 |
| MANGANESE | 4 | 0.10 | 0.12 | 0.29 | 0.03 | 0.03 | 0.29 |
| NICKEL | 4 | 0.05 | 0.00 | 0.05 | 0.05 | 0.05 | 0.05 |
| STRONTIUM | 4 | 5.29 | 0.96 | 6.60 | 4.30 | 4.30 | 6.60 |
| TITANIUM | 4 | 0.50 | 0.00 | 0.50 | 0.50 | 0.50 | 0.50 |
| ZINC | 4 | 0.03 | 0.02 | 0.06 | 0.01 | 0.01 | 0.06 |
| ZIRCONIUM | 4 | 10.00 | 0.00 | 10.00 | 10.00 | 10.00 | 10.00 |

Table 5-4. Summary of Water Chemistry Data for Upper Aquifer Near-Field Wells, Dewatering/Reinjection/ Discharge Program, 1983.

TYPE=UPPER AQUIFER AREA=NEAR FIELD REPORT YEAR=1983

BASIC AND TRACE WATER QUALITY CONSTITUENTS

| PARAMETER | N | MEAN | STD | MAX | MIN | P5 | P95 |
|---|---|---|---|---|---|---|---|
| PH | 20 | 7.29 | 0.29 | 7.70 | 6.90 | 6.90 | 7.70 |
| CONDUCTIVITY | 20 | 1513.75 | 222.35 | 2200.00 | 1200.00 | 1205.00 | 2177.50 |
| TOT DIS SOLIDS | 20 | 1195.05 | 225.19 | 1667.00 | 948.00 | 949.80 | 1665.95 |
| ALKALINITY | 20 | 462.50 | 44.27 | 522.00 | 341.00 | 342.55 | 521.85 |
| CALCIUM | 20 | 87.10 | 43.10 | 190.00 | 35.00 | 35.05 | 187.50 |
| MAGNESIUM | 20 | 92.65 | 19.07 | 140.00 | 75.00 | 75.00 | 140.00 |
| POTASSIUM | 20 | 0.43 | 0.20 | 1.05 | 0.21 | 0.21 | 1.04 |
| SODIUM | 20 | 162.30 | 35.07 | 210.00 | 110.00 | 110.15 | 210.00 |
| BICARBONATE | 20 | 542.15 | 52.86 | 621.00 | 400.00 | 401.80 | 620.50 |
| CARBONATE | 20 | 0.02 | 0.05 | 0.25 | 0.01 | 0.01 | 0.24 |
| CHLORIDE | 20 | 9.80 | 5.28 | 19.10 | 0.11 | 0.12 | 19.01 |
| NITRATE | 20 | 0.24 | 0.60 | 2.80 | 0.10 | 0.10 | 2.67 |
| SULFATE | 20 | 493.95 | 144.07 | 811.00 | 334.00 | 335.30 | 808.40 |
| FLUORIDE | 20 | 1.03 | 0.63 | 2.50 | 0.30 | 0.30 | 2.46 |
| AMMONIA | 20 | 0.22 | 0.19 | 0.65 | 0.05 | 0.05 | 0.65 |
| PHOSPHATE | 20 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| BORON | 20 | 0.25 | 0.07 | 0.37 | 0.11 | 0.11 | 0.37 |
| SILICA | 20 | 25.30 | 9.19 | 39.00 | 5.00 | 5.15 | 38.90 |
| IRON | 0 | . | . | . | . | . | . |
| DIS ORG CARBON | 20 | 6.90 | 2.31 | 11.00 | 3.00 | 3.05 | 11.00 |
| ARSENIC | 20 | 0.01 | 0.00 | 0.02 | 0.01 | 0.01 | 0.02 |
| SELENIUM | 20 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| VANADIUM | 20 | 0.10 | 0.00 | 0.10 | 0.10 | 0.10 | 0.10 |
| MOLYBDENUM | 20 | 0.12 | 0.08 | 0.40 | 0.10 | 0.10 | 0.39 |
| MERCURY | 20 | 0.30 | 0.00 | 0.30 | 0.30 | 0.30 | 0.30 |
| ALUMINUM | 5 | 0.10 | 0.00 | 0.10 | 0.10 | 0.10 | 0.10 |
| BARIUM | 5 | 0.10 | 0.00 | 0.10 | 0.10 | 0.10 | 0.10 |
| BERYLLIUM | 5 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| BISMUTH | 5 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| BROMIDE | 5 | 0.12 | 0.04 | 0.20 | 0.10 | 0.10 | 0.20 |
| CADMIUM | 5 | 1.00 | 0.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| CHROMIUM | 5 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| COPPER | 5 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| GALLIUM | 5 | 0.50 | 0.00 | 0.50 | 0.50 | 0.50 | 0.50 |
| GERMANIUM | 5 | 0.10 | 0.00 | 0.10 | 0.10 | 0.10 | 0.10 |
| LEAD | 5 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| LITHIUM | 5 | 0.10 | 0.04 | 0.13 | 0.03 | 0.03 | 0.13 |
| MANGANESE | 5 | 0.21 | 0.29 | 0.72 | 0.04 | 0.04 | 0.72 |
| NICKEL | 5 | 0.05 | 0.00 | 0.05 | 0.05 | 0.05 | 0.05 |
| STRONTIUM | 5 | 6.90 | 2.74 | 9.60 | 3.70 | 3.71 | 9.60 |
| TITANIUM | 5 | 0.50 | 0.00 | 0.50 | 0.50 | 0.50 | 0.50 |
| ZINC | 5 | 0.08 | 0.07 | 0.17 | 0.03 | 0.03 | 0.17 |
| ZIRCONIUM | 5 | 10.00 | 0.00 | 10.00 | 10.00 | 10.00 | 10.00 |

Table 5-5. Summary of Water Chemistry Data for Upper Aquifer Far-Field Wells, Dewatering/Reinjection/ Discharge Program, 1983.

TYPE=UPPER AQUIFER AREA=FAR FIELD REPORT YEAR=1983

BASIC AND TRACE WATER QUALITY CONSTITUENTS

| PARAMETER | N | MEAN | STD | MAX | MIN | P5 | P95 |
|---|---|---|---|---|---|---|---|
| PH | 1 | 9.60 | . | 9.60 | 9.60 | 9.60 | 9.60 |
| CONDUCTIVITY | 1 | 1200.00 | . | 1200.00 | 1200.00 | 1200.00 | 1200.00 |
| TOT DIS SOLIDS | 1 | 890.00 | . | 890.00 | 890.00 | 890.00 | 890.00 |
| ALKALINITY | 1 | 567.00 | . | 567.00 | 567.00 | 567.00 | 567.00 |
| CALCIUM | 1 | 4.00 | . | 4.00 | 4.00 | 4.00 | 4.00 |
| MAGNESIUM | 1 | 42.00 | . | 42.00 | 42.00 | 42.00 | 42.00 |
| POTASSIUM | 1 | 1.50 | . | 1.50 | 1.50 | 1.50 | 1.50 |
| SODIUM | 1 | 260.00 | . | 260.00 | 260.00 | 260.00 | 260.00 |
| BICARBONATE | 1 | 258.00 | . | 258.00 | 258.00 | 258.00 | 258.00 |
| CARBONATE | 1 | 2.05 | . | 2.05 | 2.05 | 2.05 | 2.05 |
| CHLORIDE | 1 | 0.14 | . | 0.14 | 0.14 | 0.14 | 0.14 |
| NITRATE | 1 | 0.10 | . | 0.10 | 0.10 | 0.10 | 0.10 |
| SULFATE | 1 | 178.00 | . | 178.00 | 178.00 | 178.00 | 178.00 |
| FLUORIDE | 1 | 2.00 | . | 2.00 | 2.00 | 2.00 | 2.00 |
| AMMONIA | 1 | 1.36 | . | 1.36 | 1.36 | 1.36 | 1.36 |
| PHOSPHATE | 1 | 0.06 | . | 0.06 | 0.06 | 0.06 | 0.06 |
| BORON | 1 | 0.19 | . | 0.19 | 0.19 | 0.19 | 0.19 |
| SILICA | 1 | 2.00 | . | 2.00 | 2.00 | 2.00 | 2.00 |
| IRON | 0 | . | . | . | . | . | . |
| DIS ORG CARBON | 1 | 6.00 | . | 6.00 | 6.00 | 6.00 | 6.00 |
| ARSENIC | 1 | 0.01 | . | 0.01 | 0.01 | 0.01 | 0.01 |
| SELENIUM | 1 | 0.01 | . | 0.01 | 0.01 | 0.01 | 0.01 |
| VANADIUM | 1 | 0.10 | . | 0.10 | 0.10 | 0.10 | 0.10 |
| MOLYBDENUM | 1 | 0.10 | . | 0.10 | 0.10 | 0.10 | 0.10 |
| MERCURY | 1 | 0.30 | . | 0.30 | 0.30 | 0.30 | 0.30 |
| ALUMINUM | 1 | 0.10 | . | 0.10 | 0.10 | 0.10 | 0.10 |
| BARIUM | 1 | 0.10 | . | 0.10 | 0.10 | 0.10 | 0.10 |
| BERYLLIUM | 1 | 0.01 | . | 0.01 | 0.01 | 0.01 | 0.01 |
| BISMUTH | 1 | 0.01 | . | 0.01 | 0.01 | 0.01 | 0.01 |
| BROMIDE | 1 | 0.10 | . | 0.10 | 0.10 | 0.10 | 0.10 |
| CADMIUM | 1 | 1.00 | . | 1.00 | 1.00 | 1.00 | 1.00 |
| CHROMIUM | 1 | 0.01 | . | 0.01 | 0.01 | 0.01 | 0.01 |
| COPPER | 1 | 0.01 | . | 0.01 | 0.01 | 0.01 | 0.01 |
| GALLIUM | 1 | 0.50 | . | 0.50 | 0.50 | 0.50 | 0.50 |
| GERMANIUM | 1 | 0.10 | . | 0.10 | 0.10 | 0.10 | 0.10 |
| LEAD | 1 | 0.01 | . | 0.01 | 0.01 | 0.01 | 0.01 |
| LITHIUM | 1 | 0.09 | . | 0.09 | 0.09 | 0.09 | 0.09 |
| MANGANESE | 1 | 0.01 | . | 0.01 | 0.01 | 0.01 | 0.01 |
| NICKEL | 1 | 0.05 | . | 0.05 | 0.05 | 0.05 | 0.05 |
| STRONTIUM | 1 | 1.95 | . | 1.95 | 1.95 | 1.95 | 1.95 |
| TITANIUM | 1 | 0.50 | . | 0.50 | 0.50 | 0.50 | 0.50 |
| ZINC | 1 | 0.01 | . | 0.01 | 0.01 | 0.01 | 0.01 |
| ZIRCONIUM | 1 | 10.00 | . | 10.00 | 10.00 | 10.00 | 10.00 |

Most of the 1983 major water chemistry means for near-field upper aquifer wells exceeded 1982 maximum values. One exception to this was a lower mean for carbonate in 1983, 0.01 mg/l compared to .44 mg/l in 1982. Comparison of mean and maximum values of 1983 and 1982 at near-field wells are listed:

| | Mean | | Maximum | |
|---|---|---|---|---|
| | 1983 | 1982 | 1983 | 1982 |
| pH | 7.2 | 7.9 | 7.7 | 8.2 |
| ec | 1488 | 1467 | 1750 | 1800 |
| TDS | 1176 | 1053 | 1636 | 1275 |
| Alk | 471 | 447 | 522 | 498 |
| Ca | 94 | 48 | 140 | 76 |
| Mg | 95 | 91 | 140 | 110 |
| K | .39 | .41 | 1.05 | .55 |
| Na | 143 | 179 | 210 | 200 |
| $HCO_3$ | 554 | 516 | 621 | 595 |
| $CO_3$ | .01 | .44 | .01 | 1.82 |
| Cl | 9.5 | 9.2 | 15.7 | 11.1 |
| $SO_4$ | 475 | 435 | 759 | 635 |
| F | .74 | 1.37 | 1.8 | 1.97 |
| $NH_3$ | .18 | .23 | .65 | .34 |
| B | .24 | .27 | .37 | .33 |
| $SIO_2$ | 32 | 26 | 39 | 32 |
| DOC | 7 | 7 | 9 | 17 |

Mean concentrations of calcium, boron, and fluoride in 1983 were slightly higher at far-field upper aquifer wells than 1982 means. Lower mean and maximum carbonate values were seen in 1983 than in 1982, as was observed in the near-field upper aquifer stations. Comparison of mean and maximum values of 1983 and 1982 for far-field wells are listed:

| | Mean | | Maximum | |
|---|---|---|---|---|
| | 1983 | 1982 | 1983 | 1982 |
| pH | 7.5 | 7.7 | 9.6 | 9.0 |
| ec | 1439 | 1623 | 1600 | 3250 |
| TDS | 1147 | 1157 | 1646 | 1608 |
| Alk | 491 | 513 | 567 | 638 |
| Ca | 80 | 67 | 190 | 130 |
| Mg | 82 | 85 | 105 | 120 |
| K | .58 | .80 | 1.5 | 2.3 |
| Na | 179 | 198 | 260 | 290 |
| $HCO_3$ | 529 | 557 | 611 | 757 |
| $CO_3$ | .26 | 2.37 | 2.05 | 18.1 |
| Cl | 9.5 | 12.1 | 19.1 | 17.4 |
| $SO_4$ | 436 | 468 | 745 | 653 |
| F | 1.1 | .86 | 2.0 | 1.7 |
| $NH_3$ | .31 | .68 | 1.36 | 3.86 |
| B | .27 | .26 | .37 | .35 |
| $SIO_2$ | 23 | 25 | 37 | 47 |
| DOC | 8 | 6 | 11 | 13 |

Qualitative comparison of 1983 water chemistry means for control, near-field, and far-field wells yielded little change in these areas of the upper aquifer for most constituents. Sulfate and chloride were in higher concentrations in the near-field and far-field wells as compared to control sites. Calcium, sulfate, and bicarbonate were found in higher concentrations in the near-field wells, while the mean for ammonia was lower in these wells. Alkalinity means increased from control wells to the far-field wells:

| | 1983 Control | 1983 Near-Field | 1983 Far-Field |
|---|---|---|---|
| Alk | 394 | 471 | 491 |
| Ca | 53 | 94 | 80 |
| $HCO_3$ | 463 | 554 | 529 |
| $SO_4$ | 344 | 475 | 435 |
| Cl | 5.4 | 9.5 | 9.5 |
| $NH_3$ | .54 | .18 | .31 |

For sodium, fluoride, postassium, and ammonia the lowest mean was observed at the near-field stations.

Of the trace elements analyzed in the upper aquifer in all areas, only Sr, Li, Br, Cd, and Mn were measureable, but were observed at low concentrations.

3. Statistical Analysis - The MANOVA for selected upper aquifer water quality parameters indicated significant variability for most constituents (at $\alpha$=0.05) in the area main effect except for pH, fluoride, chloride and marginally for bicarbonate. Significant variability for the year main effect was exhibited for pH, magnesium, sodium, chloride, fluoride:

| | Probability >F | | |
|---|---|---|---|
| Parameter | Area | Year | Area x Year |
| TDS | .0001 | .7056 | .3086 |
| conductivity | .0001 | .4749 | .3017 |
| pH | .0959 | .0001 | .0979 |
| alkalinity | .0040 | .3277 | .8571 |
| calcium | .0001 | .1551 | .3586 |
| magnesium | .0001 | .0003 | .1208 |
| sodium | .0004 | .0002 | .9556 |
| fluoride | .1283 | .0107 | .9081 |
| chloride | .0830 | .0079 | .8706 |
| bicarbonate | .0423 | .0835 | .5172 |
| sulfate | .0001 | .0985 | .1954 |

The interaction term (area x year) was not significant for any of the constituents examined. These results were very similar to the 1982 analysis for upper aquifer wells, indicating a lack of change in water quality at control, near-field, and far-field wells over time.

The evaluation of overall year and area (station type) effect was accomplished using the Hotelling-Lowley trace, Piffai's trace, Wilk's Criterion, and Roy's Maximum Root Criterion (Appendix 5-1.4). These analyses continue to show significant differences for both the area and year main effects.

The Duncan's Multiple Range Test was used to examine the nature and significance of differences in mean concentrations of water quality over time (year) and space (control, near-field, and far-field). Results are shown in Appendix 5-1.4. Examination of spatial differences indicated the following:

| Parameter | Area Significantly Different From Near-Field |
|---|---|
| TDS | control, far-field |
| conductivity | far-field |
| alkalinity | far-field |
| calcium | control, far-field |
| magnesium | control, far-field |
| sodium | far-field |
| sulfate | control, far-field |

Mean concentrations of fluoride, bicarbonate, pH, and chloride showed no significant spatial differences. These results are very similar to the 1982 analysis. Also, as previously observed, for all the constituents except calcium, the highest means from Duncan's analyses were observed in the far-field area. The highest mean for calcium occurred in the control area, as seen in 1982.

The Duncan's Multiple Range Test evaluation of differences among years resulted in the following (only those parameters with significant variability for the year main effect in the MANOVA were considered):

| Parameter | Years Significantly Different Than 1983 |
|---|---|
| pH | 1975, 1976, 1979, 1981 |
| sodium | 1976 |
| chloride | 1976 |
| fluoride | none |
| magnesium | none |

The means estimated for these parameters for the upper aquifer are as follows:

| Parameter | 1975 | 1976 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 |
|---|---|---|---|---|---|---|---|---|
| pH | 6.8 | 6.9 | 7.4 | 8.0 | 7.9 | 8.0 | 7.7 | 7.4 |
| magnesium | 65 | 63 | 88 | 79 | 92 | 82 | 85 | 85 |
| sodium | 299 | 325 | 222 | 205 | 200 | 194 | 179 | 161 |
| chloride | 17 | 18 | 7 | 13 | 14 | 11 | 11 | 9 |
| fluoride | 3.1 | 3.0 | 1.7 | 0.8 | 0.6 | 0.4 | 0.9 | 0.9 |

The means for pH and sodium show a gradual decrease since 1981, while magnesium, chloride, and fluoride concentrations are remaining fairly stable.

The MANOVA analyses and the Duncan's Multiple Range Test results indicate that, although certain constituents vary significantly in time and space, the general water quality pattern has remained unchanged over time and this pattern cannot be related to operation of the dewatering/reinjection system. No impact-related changes were apparent from these analyses.

D. Lower Aquifer

The 1983 field data for the lower aquifer far-field well (GS-17L) are shown in Appendix 5-1.3. The water level measurements (depth to water) for this well ranged from 371.5' to 372.2' in 1982, while in 1983 the levels ranged from 368.4' to 370.4', indicating a slight rise between the two years.

## 5.2 MIS MODULAR DEVELOPMENT AREA

### 1. Objectives

The lease suspension monitoring program of the MIS Modular Development area is designed to detect and evaluate any effects that the MIS retorts or surface operations have on deep aquifer, surface waters, and alluvial aquifers. Sites monitored during 1983 included surface streams, springs, alluvial and deep aquifer wells.

### 2. Methods

Sampling methods are as described in previous reports and/or the Scope of Work (RBOSC 1983). Stations included in the interim monitoring program are as follows:

| Station Class | Station Identification | |
|---|---|---|
| Type I Control | Streams | |
| | B-USGS | C-USGS |
| | Springs and Seeps | |
| | SPG-3 | |
| | SPG-4 | SPG-14 |
| | SPG-5 | SPG-MILL |
| | Alluvial Aquifer | |
| | GS-S7 | GS-S8 |
| | Deep Aquifer | |
| | GS-15L | GS-15U |
| | CE-708U | GS-9U |

| Station Class | Station Identification | |
|---|---|---|
| Type II Near Field | Streams | |
| | D-USGS | YMET3 |
| | YCOFL | YBOXFL |
| | YSEOFL | |
| | Alluvial Aquifer | |
| | GS-S27S | |
| | GS-S27A | |
| | Deep Aquifer | |
| | CE-709U | CE-702U |
| | GS-MDP2CU | CE-705AU |
| Type II Far Field | Alluvial Aquifer | |
| | GS-S24 | |
| | Deep Aquifer | |
| | GS-M3U | |

## 3. Results and Discussion

Temporal and spatial hydrologic variations have been examined for the MIS program element, using data from the above-listed stations. Temporal changes were examined by comparing 1983 univariate statistics with similar statistics for previous years, with the major focus on comparison with 1982 data. Extensive repetition of previously reported (pre-1983) data has been avoided. The 1982 data base used for comparison purposes in this report is provided in MDP Monitoring Report 11 (RBOSC 1983b). Spatial variations were evaluated by comparing control, near-field, and far-field univariate statistics for surface streams, alluvial wells and upper aquifer wells. An analysis of variance procedure was used to test the significance of observed variations and space-time interactions.

Unless noted otherwise, the parameters discussed and listed in this section and associated appendices have the following units: water chemistry constituents, milligrams per liter; mercury, micrograms per liter; pH, standard units; conductivity (specific conductance or ec), micromhos per cm; temperature, degrees Celsius.

A. Springs and Seeps

Five spring and seep monitoring stations functioned as control sites for the lease suspension or "interim" monitoring program of the MIS area. A summary of the 1983 field measurements is presented in Table 5-6. The field water quality measurements for each station are presented in Appendix 5-1.2. The parameters measured were generally comparable to the 1982 data, with the exception of increased flow during the spring due to heavy runoff and precipitation.

B. Streams

Field measurements from the near-field stream stations are contained in Appendix 5-1.2. These stations include:

- o YBOXFL - on Box Elder Gulch just upstream from the confluence with Corral Gulch
- o YCOFL - on Corral Gulch just upstream from the confluence with Box Elder Gulch
- o YMET3 - on Corral Gulch just below the confluence with Box Elder Gulch
- o YSEOFL - on Corral Gulch approximately 1.5 miles below YMET3

Table 5-6. Summary of Field Data from Control Springs and Seeps, MIS Monitoring Area, 1983.

TYPE=SPRINGS AND SEEPS AREA=CONTROL REPORT YEAR=1983

| PARAMETER | N | MEAN | STD | MAX | MIN | P5 | P95 |
|---|---|---|---|---|---|---|---|
| DEPTH | 0 | . | . | . | . | . | . |
| PH | 17 | 7.71 | 0.45 | 8.60 | 7.10 | 7.10 | 8.60 |
| CONDUCTIVITY | 17 | 1435.29 | 209.74 | 1750.00 | 1100.00 | 1100.00 | 1750.00 |
| TEMPERATURE | 17 | 12.14 | 6.83 | 26.20 | 3.50 | 3.50 | 26.20 |
| FLOW | 12 | 26.38 | 33.60 | 125.00 | 0.00 | 0.00 | 125.00 |
| TOT SUS SOLIDS | 0 | . | . | . | . | . | . |
| PRESSURE | 0 | . | . | . | . | . | . |

The 1983 field measurements of pH and conductivity were consistent with the 1982 data. Flows, however, increased markedly beginning in late April continuing into August, after extremely heavy runoff and precipitation in the spring of 1983. Flumes became either silted-in or washed-out during this peak flow period, making flow measurements impossible. The highest flow determined prior to this wash-out was 2640.7 gpm at YMET3 on April 27, 1983. As a result of high flows, conductivity values during this period were lower overall. Figure 5-5 shows a time-series plot for conductivity at station YMET3.

The 1983 water chemistry data from the surface flow stations (Appendix 5-1.1) was very similar to the 1982 data at these sites. The concentrations of major constituents increased between YMET3 and YSEOFL as seen in 1982 and earlier years. Selected 1983 means were as follows:

| Parameter | YMET3 | YSEOFL |
|---|---|---|
| pH | 7.7 | 7.5 |
| conductivity | 1363 | 1788 |
| TDS | 1068 | 1431 |
| alkalinity | 472 | 573 |
| calcium | 87 | 107 |
| magnesium | 73 | 106 |
| sodium | 168 | 215 |
| bicarbonate | 548 | 676 |
| chloride | 8.1 | 13.8 |
| sulfate | 404 | 584 |
| DOC | 7.5 | 8.8 |
| nitrate | .7 | 2.7 |

While the 1983 TDS means were slightly higher overall than the 1982 means for YMET3 and YSEOFL, the TDS values from April to June of 1983 decreased along with conductivity values during high flows. Sulfate increased from 1982 concentrations, while chloride decreased notably.

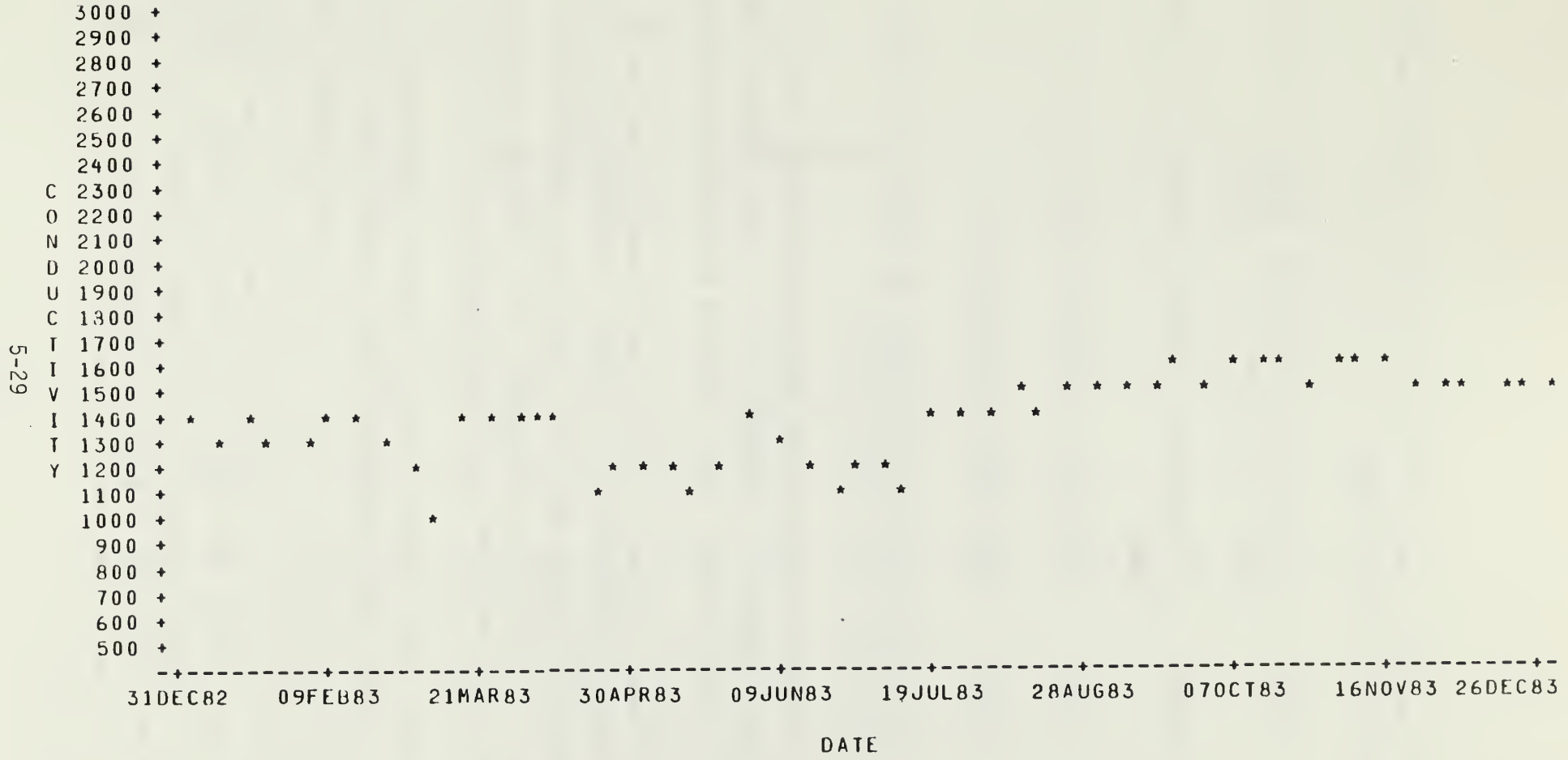



Figure 5-5. Conductivity (micromhos per cm) at YMET3, 1983.

MANOVA techniques were used to evaluate the temporal variability (1981 through 1983) at these stations:

- o YBOXFL - no significant variability except for calcium (PR>F = 0.0155) and fluoride (PR>F = 0.0339)
- o YMET3 - no significant variability except for calcium (PR>F = 0.0424)
- o YSEOFL - no significant variability except for pH (PR>F = 0.0420)
- o YCOFL - insufficient data for analysis

Thus, the differences noted between 1983 and 1982 are not generally significant statistically and indicate no trend.

Data collected at the three USGS gage stations include daily flow, conductivity, and temperature (Appendix 5-2.1). Daily sediment data were not available for this report. Other data were available through September 1983.

Table 5-7 shows a summary of flows of waters entering and leaving Tract C-a using USGS gage station data. In general, the tract area was a net producer of surface water during 1983 (i.e., more water leaves than flows onto the tract). In April and May, however, this situation was reversed due to extremely heavy runoff and precipitation upgradient from the tract.

Flows at the USGS sites were typically low from October 1982 through March 1983. In April, flows jumped markedly and increased steadily to their peak measurements through May: Station C in Box Elder Gulch had a peak flow of 48 cfs on May 28; Station B in upper Corral Gulch peaked at 78 cfs on May 31 during an alluvial mud flow which hit Station D in lower Corral Gulch on June 1 when a daily mean flow of 195 cfs was recorded. The Box Elder drainage returned to typical flows in August, however, Corral Gulch flows for the rest of the 1983 USGS water year remained higher than previous years. Figures 5-6 and 5-7 are time plots exhibiting flow means for Station C and D, respectively.

Table 5-7. Summary of Flows at USGS Gaging Stations 1983 Water Year

| Station | Flow (acre/ft) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUNE | JULY | AUG | SEPT |
| B-Corral Gulch - West | 19.0 | 8.5 | 7.9 | 4.1 | 2.3 | 7.2 | 64.1 | 968.0 | 954.0 | 177.2 | 92.1 | 76.2 |
| C-Box Elder - West | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 2.6 | 161.7 | 1340.9 | 775.6 | 36.4 | 0.0 | 0.0 |
| Total Inflow | 19.0 | 8.5 | 7.9 | 4.1 | 3.0 | 9.8 | 225.8 | 2308.9 | 1729.6 | 213.6 | 92.1 | 76.2 |
| D-Corral Gulch East (total outflow) | 34.8 | 23.7 | 30.3 | 35.3 | 40.8 | 66.7 | 164.9 | 2092.5 | 1958.0 | 213.0 | 149.7 | 181.0 |
| Outflow-Inflow | 15.8 | 15.2 | 22.4 | 31.2 | 37.8 | 56.9 | -60.9 | -216.4 | 228.4 | -0.6 | 57.6 | 104.8 |

Figure 5-6. Daily Mean Flow (cfs) at USGS Station 6, 1983 (peak flow of 48 cfs observed on May 28, 1983).

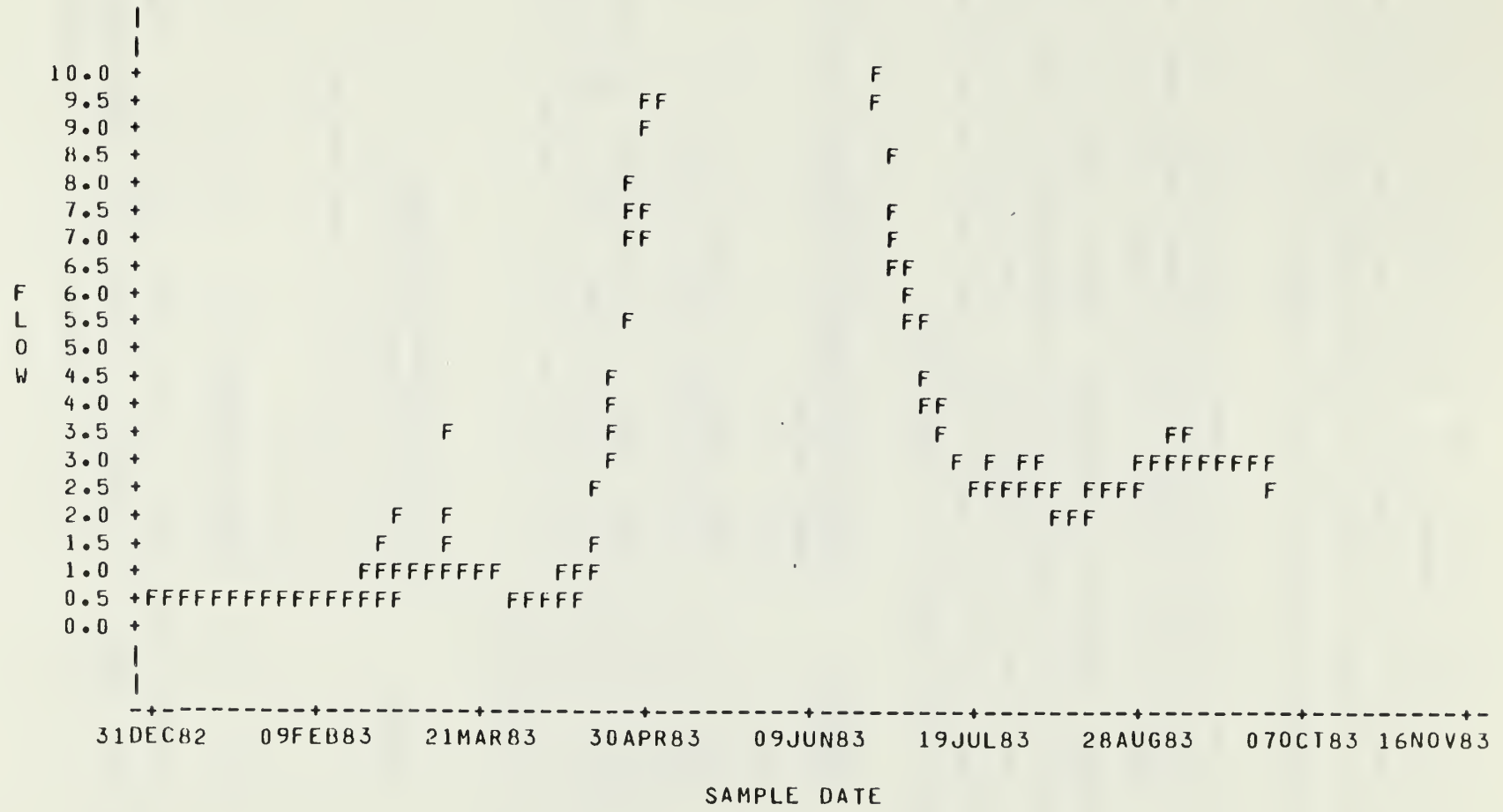



Figure 5-7. Daily Mean Flow (cfs) at USGS Station D, 1983(peak flow of 195 cfs observed on June 1, 1983).

Field water quality summaries for the USGS stations are shown in Table 5-8. Daily means for all parameters reported were lowest at Station C (Box Elder Gulch) and highest at Station D (Corral Gulch - East). Time plots for all field parameters reported are shown in Appendix 5-2.1.

Analysis of variance results indicated that mean daily flows, conductivity, and temperature were significantly different among report years for each USGS station, with all stations showing a PR>F value of 0.0001 for each parameter. The results of the Duncan's Multiple Range Test (Appendix 5-2.1) indicated the flow means in 1983 were significantly different from all other years analyzed for Stations B and C. The mean flow for Station D showed significant variability from all other years with the exception of 1978. Seasonal flow variability is shown below:

| Station | Seasons Significantly Different for Mean Flow |
|---|---|
| B | summer, winter |
| C | none |
| D | spring, summer, fall, winter |

The Duncan's Multiple Range Test for mean conductivity by season indicates no significant difference between fall and summer for Station B; summer and spring for Station C, and winter and fall for Station D. Variations by years is shown below:

| Station | Years Significantly Different From 1983 for Mean Conductivity |
|---|---|
| B | 1975 through 1982 (all years examined) |
| C | 1977, 1981 |
| D | 1975 through 1981 |

Water chemistry data collected during 1983 are found in Appendix 5-2.1. Major water chemistry parameters are summarized for each station in Tables 5-9, 5-10, and 5-11. The constituents analyzed were comparable to the 1982

Table 5-8. Summaries of Field Data from USGS Gage Stations, 1983.

U.S.G.S. GAUGING STATION = B-CORRAL GULCH - WEST

REPORT YEAR = 1983

| PARAMETER | N | MEAN | STD | MIN | MAX | P5 | P95 |
|---|---|---|---|---|---|---|---|
| DAILY MEAN FLOW | 272 | 4.35 | 8.82 | 0.00 | 78.00 | 0.02 | 24.70 |
| CONDUCTIVITY | | | | | | | |
| DAILY HIGH | 163 | 1273.64 | 197.74 | 620.00 | 1474.00 | 857.20 | 1440.00 |
| DAILY LOW | 163 | 1153.79 | 300.05 | 220.00 | 1400.00 | 404.00 | 1390.00 |
| DAILY MEAN | 163 | 1220.30 | 239.10 | 445.00 | 1428.00 | 645.40 | 1415.80 |
| TEMPERATURE | | | | | | | |
| DAILY HIGH | 181 | 12.77 | 8.22 | 0.00 | 22.80 | 0.60 | 21.89 |
| DAILY LOW | 181 | 4.58 | 4.15 | 0.00 | 10.90 | 0.00 | 10.00 |
| DAILY MEAN | 181 | 7.51 | 5.55 | 0.00 | 15.00 | 0.01 | 14.20 |
| SEDIMENT LOADING | 0 | . | . | . | . | . | . |
| SUSPENDED SOLIDS | 0 | . | . | . | . | . | . |

U.S.G.S. GAUGING STATION = C-BOX ELDER GULCH - WEST

REPORT YEAR = 1983

| PARAMETER | N | MEAN | STD | MIN | MAX | P5 | P95 |
|---|---|---|---|---|---|---|---|
| DAILY MEAN FLOW | 273 | 4.29 | 8.95 | 0.00 | 48.00 | 0.00 | 25.30 |
| CONDUCTIVITY | | | | | | | |
| DAILY HIGH | 75 | 896.00 | 379.71 | 160.00 | 1320.00 | 160.00 | 1282.00 |
| DAILY LOW | 75 | 813.33 | 390.98 | 100.00 | 1290.00 | 130.00 | 1234.00 |
| DAILY MEAN | 75 | 861.12 | 383.97 | 150.00 | 1308.00 | 162.80 | 1259.80 |
| TEMPERATURE | | | | | | | |
| DAILY HIGH | 108 | 10.20 | 5.37 | 0.40 | 27.70 | 0.50 | 16.80 |
| DAILY LOW | 108 | 3.57 | 2.61 | 0.30 | 8.70 | 0.40 | 7.40 |
| DAILY MEAN | 108 | 5.84 | 3.40 | 0.40 | 15.10 | 0.40 | 10.55 |
| SEDIMENT LOADING | 0 | . | . | . | . | . | . |
| SUSPENDED SOLIDS | 0 | . | . | . | . | . | . |

U.S.G.S. GAUGING STATION = D-CORRAL GULCH - EAST

REPORT YEAR = 1983

| PARAMETER | N | MEAN | STD | MIN | MAX | P5 | P95 |
|---|---|---|---|---|---|---|---|
| DAILY MEAN FLOW | 273 | 9.07 | 19.95 | 0.55 | 195.00 | 0.57 | 49.50 |
| CONDUCTIVITY | | | | | | | |
| DAILY HIGH | 174 | 1428.56 | 138.16 | 1047.00 | 1790.00 | 1097.50 | 1600.00 |
| DAILY LOW | 174 | 1278.73 | 297.74 | 286.00 | 1580.00 | 571.75 | 1560.00 |
| DAILY MEAN | 174 | 1376.18 | 168.40 | 826.00 | 1594.00 | 1055.25 | 1576.75 |
| TEMPERATURE | | | | | | | |
| DAILY HIGH | 261 | 14.13 | 3.57 | 8.00 | 21.20 | 9.02 | 19.90 |
| DAILY LOW | 261 | 6.95 | 2.45 | 0.70 | 12.00 | 2.72 | 10.79 |
| DAILY MEAN | 261 | 9.74 | 2.43 | 4.90 | 14.30 | 6.61 | 13.60 |
| SEDIMENT LOADING | 0 | . | . | . | . | . | . |
| SUSPENDED SOLIDS | 0 | . | . | . | . | . | . |

Table 5-9. Summary of Water Chemistry Data for USGS Station B, 1983.

U.S.G.S. GAUGING STATION = B-CORRAL GULCH - WEST

REPORT YEAR = 1983

| PARAMETER | N | MEAN | STD | MIN | MAX | P5 | P95 |
|---|---|---|---|---|---|---|---|
| CONDUCTIVITY | 3 | 1373.33 | 106.93 | 1250.00 | 1440.00 | 1250.00 | 1440.00 |
| PH | 3 | 8.30 | 0.17 | 8.10 | 8.40 | 8.10 | 8.40 |
| TOT DIS SOLIDS | 0 | . | . | . | . | . | . |
| ALKALINITY | 3 | 328.00 | 14.53 | 314.00 | 343.00 | 314.00 | 343.00 |
| AMMONIA | 3 | 0.10 | 0.04 | 0.06 | 0.13 | 0.06 | 0.13 |
| KJELDAHL N-623 | 3 | 0.90 | 0.35 | 0.70 | 1.30 | 0.70 | 1.30 |
| DIS O_PHOSPHATE | 3 | 0.02 | 0.00 | 0.02 | 0.02 | 0.02 | 0.02 |
| DIS ORG CARBON | 0 | . | . | . | . | . | . |
| CALCIUM (CA) | 3 | 130.00 | 17.32 | 120.00 | 150.00 | 120.00 | 150.00 |
| MAGNESIUM (MG) | 3 | 74.33 | 4.04 | 70.00 | 78.00 | 70.00 | 78.00 |
| SODIUM (NA) | 3 | 91.00 | 7.81 | 86.00 | 100.00 | 86.00 | 100.00 |
| POTASSIUM (K) | 3 | 2.17 | 1.27 | 1.20 | 3.60 | 1.20 | 3.60 |
| CHLORIDE (CL) | 3 | 15.00 | 3.61 | 11.00 | 18.00 | 11.00 | 18.00 |
| SULFATE (SO4) | 3 | 426.67 | 58.59 | 360.00 | 470.00 | 360.00 | 470.00 |
| FLUORIDE (F) | 3 | 0.23 | 0.06 | 0.20 | 0.30 | 0.20 | 0.30 |
| BORON (B) | 3 | 86.67 | 5.77 | 80.00 | 90.00 | 80.00 | 90.00 |

Table 5-10. Summary of Water Chemistry Data for USGS Station C, 1983.

U.S.G.S. GAUGING STATION = C-BOX ELDER GULCH - WEST

REPORT YEAR = 1983

| PARAMETER | N | MEAN | STD | MIN | MAX | P5 | P95 |
|---|---|---|---|---|---|---|---|
| CONDUCTIVITY | 2 | 1105.00 | 21.21 | 1090.00 | 1120.00 | 1090.00 | 1120.00 |
| PH | 2 | 8.25 | 0.07 | 8.20 | 8.30 | 8.20 | 8.30 |
| TOT DIS SOLIDS | 0 | . | . | . | . | . | . |
| ALKALINITY | 2 | 326.00 | 1.41 | 325.00 | 327.00 | 325.00 | 327.00 |
| AMMONIA | 2 | 0.13 | 0.01 | 0.13 | 0.14 | 0.13 | 0.14 |
| KJELDAHL N-623 | 2 | 0.85 | 0.35 | 0.60 | 1.10 | 0.60 | 1.10 |
| DIS O_PHOSPHATE | 2 | 0.02 | 0.00 | 0.02 | 0.02 | 0.02 | 0.02 |
| DIS ORG CARBON | 0 | . | . | . | . | . | . |
| CALCIUM (CA) | 2 | 109.00 | 15.56 | 98.00 | 120.00 | 98.00 | 120.00 |
| MAGNESIUM (MG) | 2 | 63.50 | 3.54 | 61.00 | 66.00 | 61.00 | 66.00 |
| SODIUM (NA) | 2 | 71.00 | 5.66 | 67.00 | 75.00 | 67.00 | 75.00 |
| POTASSIUM (K) | 2 | 2.10 | 1.70 | 0.90 | 3.30 | 0.90 | 3.30 |
| CHLORIDE (CL) | 2 | 13.00 | 2.83 | 11.00 | 15.00 | 11.00 | 15.00 |
| SULFATE (SO4) | 2 | 305.00 | 35.36 | 280.00 | 330.00 | 280.00 | 330.00 |
| FLUORIDE (F) | 2 | 0.30 | 0.00 | 0.30 | 0.30 | 0.30 | 0.30 |
| BORON (B) | 2 | 70.00 | 0.00 | 70.00 | 70.00 | 70.00 | 70.00 |

Table 5-11. Summary of Water Chemistry Data for USGS Station D, 1983.

U.S.G.S. GAUGING STATION = D-CORRAL GULCH - EAST

REPORT YEAR = 1983

| PARAMETER | N | MEAN | STD | MIN | MAX | P5 | P95 |
|---|---|---|---|---|---|---|---|
| CONDUCTIVITY | 4 | 1365.00 | 249.33 | 1130.00 | 1600.00 | 1130.00 | 1600.00 |
| PH | 4 | 8.20 | 0.24 | 7.90 | 8.40 | 7.90 | 8.40 |
| TOT DIS SOLIDS | 0 | . | . | . | . | . | . |
| ALKALINITY | 4 | 364.00 | 88.77 | 297.00 | 463.00 | 297.00 | 463.00 |
| AMMONIA | 4 | 0.09 | 0.03 | 0.05 | 0.12 | 0.05 | 0.12 |
| KJELDAHL N-623 | 4 | 1.22 | 0.61 | 0.60 | 2.00 | 0.60 | 2.00 |
| DIS O_PHOSPHATE | 4 | 0.02 | 0.02 | -0.01 | 0.03 | -0.01 | 0.03 |
| DIS ORG CARBON | 1 | 11.00 | . | 11.00 | 11.00 | 11.00 | 11.00 |
| CALCIUM (CA) | 4 | 93.25 | 12.42 | 82.00 | 110.00 | 82.00 | 110.00 |
| MAGNESIUM (MG) | 4 | 69.75 | 9.11 | 60.00 | 78.00 | 60.00 | 78.00 |
| SODIUM (NA) | 4 | 121.00 | 57.42 | 60.00 | 170.00 | 60.00 | 170.00 |
| POTASSIUM (K) | 4 | 1.97 | 0.29 | 1.60 | 2.40 | 1.80 | 2.40 |
| CHLORIDE (CL) | 4 | 13.75 | 2.22 | 12.00 | 17.00 | 12.00 | 17.00 |
| SULFATE (SO4) | 4 | 362.50 | 84.21 | 280.00 | 440.00 | 280.00 | 440.00 |
| FLUORIDE (F) | 4 | 0.40 | 0.12 | 0.30 | 0.50 | 0.30 | 0.50 |
| BORON (B) | 4 | 120.00 | 46.90 | 70.00 | 160.00 | 70.00 | 160.00 |

analysis. Specific conductivity and calcium means were higher at all sites during 1983 than in 1982. Chloride and sulfate means increased in 1983 at stations B and C. Sulfate means in 1982 at Stations B and C were 297 mg/l and 190 mg/l, respectively, compared to 427 mg/l and 305 mg/l in 1983. Mean alkalinity, sodium, fluoride, and boron concentrations were highest at Station D, while mean calcium, sulfate, chloride, magnesium, and potassium concentrations were highest at Station B.

The Duncan's Analysis (Appendix 5-2.1) for the year main effect showed significant differences between years only for DOC and fluoride. The 1983 DOC mean of 11 mg/l differed only from the 1980 mean of 19 mg/l, while the 1983 fluoride mean of .30 mg/l differed only from the 1979 mean of .88 mg/l. Greater variability occurred for the water chemistry parameters for the station main effect. The parameters showing significant differences between stations monitored during 1983 were sulfate, magnesium, calcium, pH, and conductivity.

C. Alluvial Aquifers

1. Field Data - Mean water level measurements (depth to water) during 1983 (Table 5-12) were lower than those observed during 1982, indicating wetter conditions. Minimum recordings were much less during 1983 than in 1982, while maximum levels remained stable. Water levels increased markedly in the control and near-field wells in late spring with heavy precipitation and runoff. One of the near-field wells, GS-S27A, is typically dry, but contained measurable water during 1983. The water, however, was shallow and extremely muddy, so that sampling for field water quality analysis was not possible. The far-field well, GS-S24, showed only a slight increase in water level since 1982. A time plot showing water level values at control well GS-S8 is shown in Figure 5-8.

The 1983 field parameters of alluvial aquifers for all areas were generally comparable to the 1982 data. Mean conductivities were slightly higher in the control and near-field wells, while the pH was slightly lower than seen

Table 5-12. Summaries of Field Data from Alluvial Wells, MIS Monitoring Area, 1983.

TYPE=ALLUVIAL AQUIFER AREA=CONTROL REPORT YEAR=1983

| PARAMETER | N | MEAN | STD | MAX | MIN | P5 | P95 |
|---|---|---|---|---|---|---|---|
| WATER LEVEL | 103 | 27.49 | 8.40 | 42.90 | 13.60 | 15.26 | 42.86 |
| TEMPERATURE | 2 | 9.70 | 0.57 | 10.10 | 9.30 | 9.30 | 10.10 |
| CONDUCTIVITY | 2 | 1275.00 | 247.49 | 1450.00 | 1100.00 | 1100.00 | 1450.00 |
| PH | 2 | 7.20 | 0.28 | 7.40 | 7.00 | 7.00 | 7.40 |

TYPE=ALLUVIAL AQUIFER AREA=NEAR FIELD REPORT YEAR=1983

| PARAMETER | N | MEAN | STD | MAX | MIN | P5 | P95 |
|---|---|---|---|---|---|---|---|
| WATER LEVEL | 52 | 20.40 | 4.89 | 26.50 | 13.10 | 13.29 | 26.40 |
| TEMPERATURE | 4 | 9.80 | 0.75 | 10.40 | 8.70 | 8.70 | 10.40 |
| CONDUCTIVITY | 4 | 1550.00 | 108.01 | 1700.00 | 1450.00 | 1450.00 | 1700.00 |
| PH | 4 | 7.27 | 0.10 | 7.40 | 7.20 | 7.20 | 7.40 |

TYPE=ALLUVIAL AQUIFER AREA=FAR FIELD REPORT YEAR=1983

| PARAMETER | N | MEAN | STD | MAX | MIN | P5 | P95 |
|---|---|---|---|---|---|---|---|
| WATER LEVEL | 4 | 9.57 | 0.93 | 10.80 | 8.80 | 8.80 | 10.80 |
| TEMPERATURE | 1 | 9.20 | . | 9.20 | 9.20 | 9.20 | 9.20 |
| CONDUCTIVITY | 1 | 1800.00 | . | 1800.00 | 1800.00 | 1800.00 | 1800.00 |
| PH | 1 | 7.20 | . | 7.20 | 7.20 | 7.20 | 7.20 |

Figure 5-8. Water Levels (feet below surface) at Alluvial Well GS-S8, 1983.

in 1982. These changes were not great. Far-field means for 1983 showed no differences from the 1982 means.

Spatial variation in water levels from the control to near-field to far-field areas (Table 5-12) was due to differences in well location and alluvial thickness. As seen in 1982, alluvial pH showed no variation across the three monitoring areas, while conductivity increased in the down-gradient direction.

Additional alluvial aquifer data were collected during 1983 to examine effects of increased flow in the alluvial system. The data were collected primarily in Yellow Creek and are shown in Table 5-13. All water levels increased compared to previous data. Field water quality parameters showed little variation compared to the 1982 data, with the exception of increased conductivity measurements in the October samples. This was probably due to leaching of materials from surrounding soils and alluvium.

2. Water Chemistry Data - Water chemistry data for alluvial wells are presented in Appendix 5-1.1. Parameters analyzed during 1983 were generally comparable to 1982 data at control, near-field, and far-field wells. TDS values, however, were slightly higher in the control and near-field wells in 1983:

| | Means | |
|---|---|---|
| Type | 1983 TDS | 1982 TDS |
| Control | 869 | 790 |
| Near-field | 1163 | 1089 |
| Far-field | 1380 | 1358 |

The mean sulfate concentration was also slightly higher in the control wells - 317.8 in 1983 compared to 269.7 in 1982. Nitrate concentrations were generally higher in all areas during 1983, while all pH means were slightly lower than observed in 1982. Summaries of the 1983 water chemistry data for alluvial aquifer control, near-field, and far-field wells are shown in Tables 5-14, 5-15, and 5-16.

Table 5-13. Additional Field Data of Alluvial Aquifers, 1983.

| Well | Date | Depth (ft) To Water | pH | Conductivity | °C |
|---|---|---|---|---|---|
| GS-S27S | 6/23/83 | 21.7 | 7.7 | 1450 | 9.6 |
| GS-S27A | 6/23/83 | 16.0 | | | |
| GS-S28AD | 6/23/83 | 5.1 | 7.2 | 2200 | 7.8 |
| GS-S28AS | 6/23/83 | 4.3 | 7.1 | 2200 | 7.2 |
| GS-S28D | 6/23/83 | 7.6 | 7.4 | 2200 | 7.4 |
| GS-S28S | 6/23/83 | 7.1 | 7.3 | 1900 | 7.5 |
| GS-S22 | 6/23/83 | 53.2 | 7.3 | 2100 | 8.7 |
| GS-S29AD | 6/24/83 | 21.3 | 7.6 | 2000 | 7.8 |
| | 10/4/83 | 20.5 | 7.2 | 2400 | 8.3 |
| GS-S29AS | 6/24/83 | 21.9 | 7.5 | 2900 | 8.3 |
| | 10/4/83 | 21.1 | 7.1 | 3300 | 8.4 |
| GS-S29D | 6/24/83 | 12.1 | 7.6 | 4600 | 6.9 |
| | 10/4/83 | 15.5 | 7.3 | 6100 | 8.4 |
| GS-S29S | 6/24/83 | 14.2 | 7.5 | 4050 | 6.7 |
| | 10/4/83 | 16.1 | 7.2 | 5000 | 7.8 |
| GS-S30A | 6/24/83 | 18.2 | 7.8 | 2050 | 8.7 |
| | 10/4/83 | 15.4 | 7.5 | 2450 | 9.1 |
| GS-S30 | 6/24/83 | 18.6 | 7.8 | 2000 | 8.4 |
| | 10/4/83 | 15.7 | 7.4 | 2400 | 8.7 |

Table 5-14. Summary of Water Chemistry Data for Alluvial Aquifer Control Wells, Monitoring Area, 1983.

TYPE=ALLUVIAL AQUIFER AREA=CONTROL REPORT YEAR=1983

BASIC AND TRACE WATER QUALITY CONSTITUENTS

| PARAMETER | N | MEAN | STD | MAX | MIN | P5 | P95 |
|---|---|---|---|---|---|---|---|
| PH | 4 | 7.17 | 0.17 | 7.40 | 7.00 | 7.00 | 7.40 |
| CONDUCTIVITY | 4 | 1187.50 | 193.11 | 1450.00 | 1000.00 | 1000.00 | 1450.00 |
| TOT DIS SOLIDS | 4 | 869.25 | 197.23 | 1147.00 | 682.00 | 682.00 | 1147.00 |
| ALKALINITY | 4 | 398.75 | 33.32 | 434.00 | 366.00 | 366.00 | 434.00 |
| CALCIUM | 4 | 104.25 | 18.23 | 130.00 | 87.00 | 87.00 | 130.00 |
| MAGNESIUM | 4 | 64.50 | 12.92 | 83.00 | 53.00 | 53.00 | 83.00 |
| POTASSIUM | 4 | 1.19 | 0.17 | 1.33 | 1.02 | 1.02 | 1.33 |
| SODIUM | 4 | 90.50 | 17.23 | 110.00 | 76.00 | 76.00 | 110.00 |
| BICARBONATE | 4 | 469.50 | 35.97 | 508.00 | 435.00 | 435.00 | 508.00 |
| CARBONATE | 4 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| CHLORIDE | 4 | 13.52 | 3.07 | 15.90 | 9.20 | 9.20 | 15.90 |
| NITRATE | 4 | 3.92 | 3.69 | 8.00 | 0.80 | 0.80 | 8.00 |
| SULFATE | 4 | 317.75 | 116.59 | 484.00 | 214.00 | 214.00 | 484.00 |
| FLUORIDE | 4 | 0.35 | 0.04 | 0.40 | 0.30 | 0.30 | 0.40 |
| AMMONIA | 4 | 0.06 | 0.02 | 0.08 | 0.05 | 0.05 | 0.08 |
| PHOSPHATE | 4 | 0.04 | 0.04 | 0.10 | 0.02 | 0.02 | 0.10 |
| BORON | 4 | 0.26 | 0.04 | 0.31 | 0.21 | 0.21 | 0.31 |
| SILICA | 4 | 22.25 | 1.26 | 24.00 | 21.00 | 21.00 | 24.00 |
| IRON | 0 | . | . | . | . | . | . |
| DIS ORG CARBON | 4 | 9.00 | 1.63 | 11.00 | 7.00 | 7.00 | 11.00 |
| ARSENIC | 4 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| SELENIUM | 4 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| VANADIUM | 4 | 0.10 | 0.00 | 0.10 | 0.10 | 0.10 | 0.10 |
| MOLYBDENUM | 4 | 0.10 | 0.00 | 0.10 | 0.10 | 0.10 | 0.10 |
| MERCURY | 4 | 0.30 | 0.00 | 0.30 | 0.30 | 0.30 | 0.30 |
| ALUMINUM | 0 | . | . | . | . | . | . |
| BARIUM | 0 | . | . | . | . | . | . |
| BERYLLIUM | 0 | . | . | . | . | . | . |
| BISMUTH | 0 | . | . | . | . | . | . |
| BROMIDE | 0 | . | . | . | . | . | . |
| CADMIUM | 0 | . | . | . | . | . | . |
| CHROMIUM | 0 | . | . | . | . | . | . |
| COPPER | 0 | . | . | . | . | . | . |
| GALLIUM | 0 | . | . | . | . | . | . |
| GERMANIUM | 0 | . | . | . | . | . | . |
| LEAD | 0 | . | . | . | . | . | . |
| LITHIUM | 0 | . | . | . | . | . | . |
| MANGANESE | 0 | . | . | . | . | . | . |
| NICKEL | 0 | . | . | . | . | . | . |
| STRONTIUM | 0 | . | . | . | . | . | . |
| TITANIUM | 0 | . | . | . | . | . | . |
| ZINC | 0 | . | . | . | . | . | . |
| ZIRCONIUM | 0 | . | . | . | . | . | . |

Table 5-15. Summary of Water Chemistry Data for Alluvial Aquifer Near-field Wells, MIS Monitoring Area, 1983.

TYPE=ALLUVIAL AQUIFER AREA=NEAR FIELD REPORT YEAR=1983

BASIC AND TRACE WATER QUALITY CONSTITUENTS

| PARAMETER | N | MEAN | STD | MAX | MIN | P5 | P95 |
|---|---|---|---|---|---|---|---|
| PH | 4 | 7.27 | 0.10 | 7.40 | 7.20 | 7.20 | 7.40 |
| CONDUCTIVITY | 4 | 1550.00 | 108.01 | 1700.00 | 1450.00 | 1450.00 | 1700.00 |
| TOT DIS SOLIDS | 4 | 1162.50 | 75.69 | 1265.00 | 1092.00 | 1092.00 | 1265.00 |
| ALKALINITY | 4 | 508.25 | 36.50 | 554.00 | 466.00 | 466.00 | 554.00 |
| CALCIUM | 4 | 111.00 | 2.00 | 114.00 | 110.00 | 110.00 | 114.00 |
| MAGNESIUM | 4 | 90.00 | 3.16 | 93.00 | 86.00 | 86.00 | 93.00 |
| POTASSIUM | 4 | 1.76 | 0.22 | 2.00 | 1.49 | 1.49 | 2.00 |
| SODIUM | 4 | 146.00 | 7.12 | 154.00 | 140.00 | 140.00 | 154.00 |
| BICARBONATE | 4 | 598.00 | 46.95 | 658.00 | 545.00 | 545.00 | 658.00 |
| CARBONATE | 4 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| CHLORIDE | 4 | 9.44 | 6.22 | 13.20 | 0.15 | 0.15 | 13.20 |
| NITRATE | 4 | 2.42 | 2.53 | 4.90 | 0.10 | 0.10 | 4.90 |
| SULFATE | 4 | 455.25 | 41.41 | 507.00 | 409.00 | 409.00 | 507.00 |
| FLUORIDE | 4 | 0.42 | 0.19 | 0.70 | 0.30 | 0.30 | 0.70 |
| AMMONIA | 4 | 1.23 | 1.40 | 3.03 | 0.05 | 0.05 | 3.03 |
| PHOSPHATE | 4 | 0.11 | 0.07 | 0.18 | 0.04 | 0.04 | 0.18 |
| BORON | 4 | 0.28 | 0.02 | 0.30 | 0.25 | 0.25 | 0.30 |
| SILICA | 4 | 23.25 | 0.96 | 24.00 | 22.00 | 22.00 | 24.00 |
| IRON | 0 | . | . | . | . | . | . |
| DIS ORG CARBON | 4 | 11.50 | 8.50 | 24.00 | 5.00 | 5.00 | 24.00 |
| ARSENIC | 4 | 0.01 | 0.00 | 0.02 | 0.01 | 0.01 | 0.02 |
| SELENIUM | 4 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| VANADIUM | 4 | 0.10 | 0.00 | 0.10 | 0.10 | 0.10 | 0.10 |
| MOLYBDENUM | 4 | 0.10 | 0.00 | 0.10 | 0.10 | 0.10 | 0.10 |
| MERCURY | 4 | 0.30 | 0.00 | 0.30 | 0.30 | 0.30 | 0.30 |
| ALUMINUM | 1 | 0.10 | . | 0.10 | 0.10 | 0.10 | 0.10 |
| BARIUM | 1 | 0.10 | . | 0.10 | 0.10 | 0.10 | 0.10 |
| BERYLLIUM | 1 | 0.01 | . | 0.01 | 0.01 | 0.01 | 0.01 |
| BISMUTH | 1 | 0.01 | . | 0.01 | 0.01 | 0.01 | 0.01 |
| BROMIDE | 1 | 0.10 | . | 0.10 | 0.10 | 0.10 | 0.10 |
| CADMIUM | 0 | . | . | . | . | . | . |
| CHROMIUM | 1 | 0.01 | . | 0.01 | 0.01 | 0.01 | 0.01 |
| COPPER | 1 | 0.01 | . | 0.01 | 0.01 | 0.01 | 0.01 |
| GALLIUM | 1 | 0.50 | . | 0.50 | 0.50 | 0.50 | 0.50 |
| GERMANIUM | 1 | 0.10 | . | 0.10 | 0.10 | 0.10 | 0.10 |
| LEAD | 1 | 0.01 | . | 0.01 | 0.01 | 0.01 | 0.01 |
| LITHIUM | 1 | 0.01 | . | 0.01 | 0.01 | 0.01 | 0.01 |
| MANGANESE | 1 | 0.07 | . | 0.07 | 0.07 | 0.07 | 0.07 |
| NICKEL | 1 | 0.05 | . | 0.05 | 0.05 | 0.05 | 0.05 |
| STRONTIUM | 1 | 2.38 | . | 2.38 | 2.38 | 2.38 | 2.38 |
| TITANIUM | 1 | 0.50 | . | 0.50 | 0.50 | 0.50 | 0.50 |
| ZINC | 1 | 0.09 | . | 0.09 | 0.09 | 0.09 | 0.09 |
| ZIRCONIUM | 1 | 10.00 | . | 10.00 | 10.00 | 10.00 | 10.00 |

Table 5-16. Summary of Water Chemistry Data for Alluvial Aquifer Far-Field Wells, MIS Monitoring Area, 1983.

TYPE=ALLUVIAL AQUIFER AREA=FAR FIELD REPORT YEAR=1983

BASIC AND TRACE WATER QUALITY CONSTITUENTS

| PARAMETER | N | MEAN | STD | MAX | MIN | P5 | P95 |
|---|---|---|---|---|---|---|---|
| PH | 2 | 7.20 | 0.00 | 7.20 | 7.20 | 7.20 | 7.20 |
| CONDUCTIVITY | 2 | 1800.00 | 0.00 | 1800.00 | 1800.00 | 1800.00 | 1800.00 |
| TOT DIS SOLIDS | 2 | 1380.00 | 65.05 | 1426.00 | 1334.00 | 1334.00 | 1426.00 |
| ALKALINITY | 2 | 551.00 | 18.38 | 564.00 | 538.00 | 538.00 | 564.00 |
| CALCIUM | 2 | 131.50 | 16.26 | 143.00 | 120.00 | 120.00 | 143.00 |
| MAGNESIUM | 2 | 113.50 | 4.95 | 117.00 | 110.00 | 110.00 | 117.00 |
| POTASSIUM | 2 | 2.22 | 0.53 | 2.60 | 1.85 | 1.85 | 2.60 |
| SODIUM | 2 | 175.50 | 21.92 | 191.00 | 160.00 | 160.00 | 191.00 |
| BICARBONATE | 2 | 648.00 | 25.46 | 666.00 | 630.00 | 630.00 | 666.00 |
| CARBONATE | 2 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| CHLORIDE | 2 | 19.80 | 5.09 | 23.40 | 16.20 | 16.20 | 23.40 |
| NITRATE | 2 | 2.75 | 2.33 | 4.40 | 1.10 | 1.10 | 4.40 |
| SULFATE | 2 | 581.00 | 28.28 | 601.00 | 561.00 | 561.00 | 601.00 |
| FLUORIDE | 2 | 0.38 | 0.02 | 0.40 | 0.37 | 0.37 | 0.40 |
| AMMONIA | 2 | 0.63 | 0.82 | 1.21 | 0.05 | 0.05 | 1.21 |
| PHOSPHATE | 2 | 0.04 | 0.01 | 0.05 | 0.03 | 0.03 | 0.05 |
| BORON | 2 | 0.46 | 0.21 | 0.61 | 0.31 | 0.31 | 0.61 |
| SILICA | 2 | 21.00 | 2.83 | 23.00 | 19.00 | 19.00 | 23.00 |
| IRON | 0 | . | . | . | . | . | . |
| DIS ORG CARBON | 2 | 8.50 | 0.71 | 9.00 | 8.00 | 8.00 | 9.00 |
| ARSENIC | 2 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| SELENIUM | 2 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| VANADIUM | 2 | 0.10 | 0.00 | 0.10 | 0.10 | 0.10 | 0.10 |
| MOLYBDENUM | 2 | 0.10 | 0.00 | 0.10 | 0.10 | 0.10 | 0.10 |
| MERCURY | 2 | 0.30 | 0.00 | 0.30 | 0.30 | 0.30 | 0.30 |
| ALUMINUM | 0 | . | . | . | . | . | . |
| BARIUM | 0 | . | . | . | . | . | . |
| BERYLLIUM | 0 | . | . | . | . | . | . |
| BISMUTH | 0 | . | . | . | . | . | . |
| BROMIDE | 0 | . | . | . | . | . | . |
| CADMIUM | 0 | . | . | . | . | . | . |
| CHROMIUM | 0 | . | . | . | . | . | . |
| COPPER | 0 | . | . | . | . | . | . |
| GALLIUM | 0 | . | . | . | . | . | . |
| GERMANIUM | 0 | . | . | . | . | . | . |
| LEAD | 0 | . | . | . | . | . | . |
| LITHIUM | 0 | . | . | . | . | . | . |
| MANGANESE | 0 | . | . | . | . | . | . |
| NICKEL | 0 | . | . | . | . | . | . |
| STRONTIUM | 0 | . | . | . | . | . | . |
| TITANIUM | 0 | . | . | . | . | . | . |
| ZINC | 0 | . | . | . | . | . | . |
| ZIRCONIUM | 0 | . | . | . | . | . | . |

3. Statistical Analysis - The results of the alluvial aquifer MANOVA for water chemistry constitutents indicated that the majority of major constituents were significantly variable (at $\alpha$=0.05) for the main effects of area (control, near-field, far-field) and year:

| | Probability >F | | |
|---|---|---|---|
| Parameter | Area | Year | Area x Year |
| TDS | .0001 | .0004 | .0097 |
| conductivity | .0001 | .0001 | .4017 |
| pH | .0001 | .0001 | .0002 |
| alkalinity | .0001 | .3179 | .5140 |
| calcium | .0010 | .0113 | .6426 |
| magnesium | .0001 | .0062 | .3555 |
| sodium | .0001 | .0008 | .8381 |
| fluoride | .2704 | .0001 | .9944 |
| chloride | .0010 | .0580 | .9650 |
| bicarbonate | .0001 | .0052 | .3890 |
| sulfate | .0001 | .0001 | .0626 |

The interaction term (area x year) was significant for TDS and pH. These values are essentially the same as was seen after the 1982 analysis, indicating the spatial pattern of alluvial water quality variability has not changed significantly over time. Thus, no development-related impacts are indicated in the alluvial water quality.

A Duncan's Multiple Range Test was used to examine the nature and significance of difference in means of alluvial water quality (Appendix 5-1.4):

| Parameter | Area Significantly Different From Near-Field |
|---|---|
| TDS | control, far-field |
| conductivity | control, far-field |
| pH | control, far-field |
| alkalinity | control |
| calcium | control, far-field |
| magnesium | control, far-field |
| sodium | control, far-field |
| fluoride | neither |
| chloride | far-field |
| bicarbonate | control |
| sulfate | control, far-field |

For most parameters, the near-field water quality was significantly different from the control and far-field areas. For most constituents the lowest means occurred in the control stations, while the highest means were observed in the far-field stations. Exceptions were observed for pH, alkalinity, calcium, and fluoride, which exhibited the greatest means at the near-field stations.

The 1983 means were similar to the 1982 means. None of the changes over the years considered are of great magnitude. Means for the years used in analyses are shown below. Only those parameters with significant variability for the year main effect in the MANOVA were considered here:

| Parameter | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 |
|---|---|---|---|---|---|---|---|---|---|
| TDS | 870 | 937 | 1058 | 835 | 1037 | 792 | 1047 | 1053 | 1089 |
| conductivity | 1175 | 1311 | 1460 | 1383 | 2007 | 1088 | 1365 | 1475 | 1455 |
| pH | 6.5 | 6.4 | 6.8 | 7.6 | 7.3 | 7.6 | 7.5 | 7.6 | 7.2 |
| calcium | 90 | 89 | 64 | 81 | 96 | 95 | 116 | 106 | 112 |
| magnesium | 58 | 65 | 91 | 58 | 73 | 59 | 86 | 84 | 85 |
| sodium | 140 | 146 | 167 | 193 | 143 | 90 | 117 | 131 | 130 |
| fluoride | 0.4 | 0.3 | 0.2 | 0.1 | 0.3 | 0.3 | 0.2 | 0.3 | 0.4 |
| bicarbonate | 479 | 476 | 538 | 450 | 541 | 464 | 520 | 552 | 557 |
| sulfate | 291 | 345 | 397 | 318 | 420 | 266 | 434 | 421 | 425 |

D. Upper Aquifer

1. Field Data - Summaries of field data from control, near-field, and far-field areas for the upper aquifer are shown in Table 5-17. Field measurements by station are found in Appendix 5-1.3.

Water level means cannot be compared accurately to the 1982 means because of changes in monitoring locations and schedules made during 1983. Mean water levels (depth to water) of most wells in all monitoring areas rose during

Table 5-17. Summary of Field Data from Upper Aquifer Wells, MIS Monitoring Area, 1983.

TYPE=UPPER AQUIFER AREA=CONTROL REPORT YEAR=1983

| PARAMETER | N | MEAN | STD | MAX | MIN | P5 | P95 |
|---|---|---|---|---|---|---|---|
| WATER LEVEL | 117 | 531.49 | 127.52 | 632.10 | 42.50 | 297.66 | 622.90 |
| TEMPERATURE | 13 | 13.69 | 1.43 | 15.20 | 10.80 | 10.80 | 15.20 |
| CONDUCTIVITY | 13 | 1609.62 | 407.68 | 2450.00 | 1200.00 | 1200.00 | 2450.00 |
| PH | 13 | 7.38 | 0.34 | 8.00 | 6.90 | 6.90 | 8.00 |

TYPE=UPPER AQUIFER AREA=NEAR FIELD REPORT YEAR=1983

| PARAMETER | N | MEAN | STD | MAX | MIN | P5 | P95 |
|---|---|---|---|---|---|---|---|
| WATER LEVEL | 207 | 264.02 | 190.39 | 591.90 | 23.70 | 25.52 | 589.62 |
| TEMPERATURE | 16 | 12.77 | 2.08 | 16.00 | 10.10 | 10.10 | 16.00 |
| CONDUCTIVITY | 16 | 1456.25 | 175.95 | 1750.00 | 1200.00 | 1200.00 | 1750.00 |
| PH | 16 | 7.29 | 0.32 | 7.70 | 6.90 | 6.90 | 7.70 |

TYPE=UPPER AQUIFER AREA=FAR FIELD REPORT YEAR=1983

| PARAMETER | N | MEAN | STD | MAX | MIN | P5 | P95 |
|---|---|---|---|---|---|---|---|
| WATER LEVEL | 8 | 113.94 | 140.55 | 284.70 | 11.20 | 11.20 | 284.70 |
| TEMPERATURE | 5 | 9.62 | 2.24 | 13.50 | 7.70 | 7.70 | 13.50 |
| CONDUCTIVITY | 5 | 1530.00 | 599.58 | 2600.00 | 1200.00 | 1200.00 | 2600.00 |
| PH | 5 | 8.94 | 1.20 | 9.60 | 6.80 | 6.80 | 9.60 |

1983 due to heavy snow melt and precipitation in the spring. Water levels at control and near-field wells remained elevated throughout 1983. Figures 5-9 and 5-10 are time plots exhibiting water levels in wells CE-705AU (in Box Elder Gulch) and well CE-709U (in Corral Gulch) respectively. The water level mean at the far-field well, GS-M3U, was consistent with that well's 1980-1983 mean of 11.64 feet.

The pH means at all monitoring sites show little appreciable change, with the control and near-field pH means being slightly lower than observed in 1982.

At the near-field wells, the conductivity was essentially unchanged from 1982. The control well mean conductivity, however, increased to 1800 micromhos per cm in 1983 from 1450 micromhos per cm in 1982. The mean conductivity of 1262.5 micromhos per cm for the far-field well, GS-M3U, is typical of that well.

Contrary to normal trends, conductivity decreased in the down-gradient direction, although minimum values in all areas was 1200 micromhos per cm. One of the control wells, GS-15U, had an unusually high conductivity measurement of 2450 micromhos per cm which may have biased the control mean estimation. The upper aquifer pH was lower in the control and near-field areas, while the far-field pH mean of 9.0 is typical of well GS-M3U.

2. Water Chemistry - Upper aquifer water chemistry data are presented in Appendix 5-1.1. Only one of the control wells, GS-15U, was sampled for water chemistry analysis during 1983. Mean levels of the water chemistry parameters are compared to the 1982 control well means:

Figure 5-9. Water Levels (feet below surface) at Upper Aquifer Well CE-705AU, 1983.

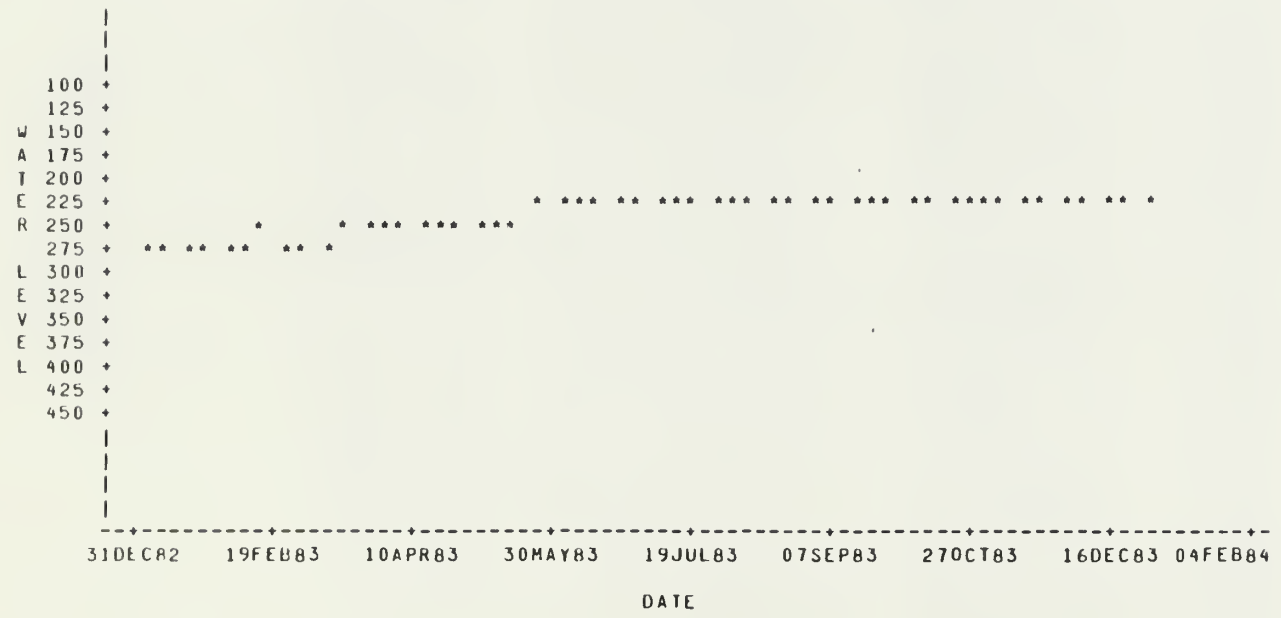



Figure 5-10. Water Levels (feet below surface) at Upper Aquifer Well CE-709U, 1983.

| | Mean | |
|---|---|---|
| Parameter | 1983 | 1982 |
| pH | 8.0 | 8.2 |
| ec | 1850 | 1100 |
| TDS | 1672 | 1093 |
| Ca | 88 | 93 |
| Mg | 130 | 76 |
| K | .74 | .63 |
| Na | 250 | 160 |
| $HCO_3$ | 578 | 578 |
| Cl | 11 | 11.3 |
| $SO_4$ | 770 | 423 |
| F | .60 | .30 |
| $NH_3$ | .22 | .22 |
| B | .37 | .27 |
| DOC | 4.0 | 4.3 |
| Alk | 494 | 492 |

Conductivity, TDS, sodium, magnesium, and sulfate were notably higher than in 1982. The reduction in 1983 sample size explains this difference relative to earlier means of control wells, as data collected at GS-15U were weighted relatively more heavily in the 1983 mean estimate. The 1983 means were typical of well GS-15U compared with the last three years of data.

The near-field upper aquifer wells were monitored regularly for water chemistry analysis during 1983. Mean concentrations of major ions were very similar to the means observed in 1982:

| | Mean | | Maximum | |
|---|---|---|---|---|
| Parameter | 1983 | 1982 | 1983 | 1982 |
| pH | 7.3 | 7.7 | 7.7 | 8.2 |
| ec | 1456 | 1428 | 1750 | 1800 |
| TDS | 1156 | 1079 | 1646 | 1420 |
| Alk | 478 | 477 | 522 | 566 |

| | Mean | | Maximum | |
|---|---|---|---|---|
| Parameter | 1983 | 1982 | 1983 | 1982 |
| Ca | 88 | 66 | 190 | 130 |
| Mg | 89 | 84 | 140 | 120 |
| K | .4 | .5 | 1.1 | 1.8 |
| Na | 158 | 176 | 210 | 210 |
| $HCO_3$ | 560 | 559 | 621 | 657 |
| Cl | 11 | 10 | 19 | 17 |
| $SO_4$ | 455 | 420 | 759 | 647 |
| F | .9 | 1.1 | 1.8 | 2.0 |
| $NH_3$ | .2 | .3 | .7 | .7 |
| DOC | 8 | 8 | 13 | 17 |

One well, GS-M3U, was sampled for water chemistry analysis one time during 1983 for the far-field upper aquifer area. The 1983 means for major constituents are compared to the 1982 means:

| | Mean | |
|---|---|---|
| Parameter | 1983 | 1982 |
| pH | 9.6 | 8.3 |
| ec | 1200 | 2375 |
| TDS | 890 | 1033 |
| Alk | 567 | 521 |
| Ca | 4 | 4 |
| Mg | 42 | 78 |
| K | 1.5 | 1.8 |
| Na | 260 | 245 |
| $HCO_3$ | 258 | 328 |
| Cl | 14 | 15.6 |
| $SO_4$ | 178 | 494 |
| F | 2 | .9 |
| $NH_3$ | 1.4 | 2.5 |
| DOC | 6 | 7 |

Most 1983 means were considerably lower than 1982 means, except for pH, alkalinity, and sodium. These means are typical of well GS-M3U.

3. Statistical Analysis - The results of the MANOVA for selected water quality constituents indicate that, for most parameters, significant variability was observed in all main effects:

| | Probability >F | | |
|---|---|---|---|
| Parameter | Area | Year | Area x Year |
| TDS | .0004 | .2421 | .0064 |
| conductivity | .0654 | .0591 | .0001 |
| pH | .0001 | .0001 | .0001 |
| alkalinity | .2212 | .0008 | .0001 |
| calcium | .0001 | .0445 | .0275 |
| magnesium | .0001 | .0002 | .0002 |
| sodium | .8357 | .0001 | .0002 |
| fluoride | .0018 | .0001 | .0001 |
| chloride | .0246 | .0010 | .0010 |
| bicarbonate | .0006 | .0001 | .0004 |
| sulfate | .0001 | .0036 | .0026 |

For area main effect, all constituents were significantly variable except for sodium, alkalinity, and somewhat for conductivity. Significant temporal variability (year main effect) was noted for all constituents except TDS and somewhat for conductivity and calcium. All parameters tested exhibited significant variability for the interaction term (year x area). These findings are consistent with the 1982 analysis.

A Duncan's Multiple Range Test (Appendix 5-1.4) was employed to examine differences in means of constituents for which significant main effect terms were observed from the MANOVA:

| Parameter | Area Significantly Different From Near-Field |
|---|---|
| TDS | control |
| pH | control, far-field |
| Ca | control, far-field |
| Mg | control, far-field |
| F | control, far-field |
| Cl | control |
| $HCO_3$ | far-field |
| $SO_4$ | control, far-field |

All three monitoring areas (control, near-field, far-field) were significantly different for sulfate, calcium, and pH, as seen in 1982. The control stations had the highest means for sulfate, magnesium, calcium, conductivity, and TDS. Chloride and pH means were highest in the far-field stations.

The year for which means were significantly different from 1983 are as follows:

| Parameter | Years Significantly Different From 1983 |
|---|---|
| pH | 1975, 1976, 1979, 1980, 1981 |
| Alk | 1976 |
| Ca | 1978 |
| Na | 1976 |
| Cl | 1976 |
| $HCO_3$ | 1976 |

Means for previous years for sulfate, fluoride, magnesium, conductivity, and TDS showed no significant difference from the 1983 data.

Differences in means over monitoring years are summarized as follows:

| Parameter | Means | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1975 | 1976 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 |
| pH | 6.7 | 6.8 | 7.6 | 8.0 | 8.0 | 8.1 | 7.8 | 7.5 |
| alkalinity | 663 | 824 | 373 | 492 | 546 | 491 | 475 | 484 |
| calcium | 76 | 54 | 35 | 72 | 76 | 61 | 61 | 83 |
| sodium | 323 | 408 | 213 | 217 | 194 | 199 | 178 | 168 |
| chloride | 17 | 22 | 7 | 12 | 12 | 12 | 11 | 9 |
| bicarbonate | 777 | 942 | 440 | 575 | 582 | 502 | 529 | 544 |

These results indicate that, after an increase in pH from 1975 to 1981, a decreasing trend is beginning to develop. Calcium only differs with any significance with the 1978 mean. Sodium and chloride means are decreasing with time, while the 1983 alkalinity and bicarbonate means are consistent with previous years. In general, mean concentrations in recent years have been fairly stable and development-related impacts are not evident.

E. Lower Aquifer

Well GS-15L was included as a control station in the MIS area hydrology monitoring program (Appendix 5-1.3). Water levels (depth to water) rose slightly during 1983, with a mean of 367.3 feet compared to the 1982 mean of 369.1 feet. The means for pH and conductivity in 1983 were 8.0 and 3013 micromhos per cm, respectively. These means are comparable to the 1982 data and are characteristic of well GS-15L.

A single water chemistry sample (Table 5-18) collected during 1983 showed concentrations typical of GS-15L when comparing these means with water chemistry summaries of data collected over the past three years from this well.

Table 5-18. Summary of Water Chemistry Data, Lower Aquifer Well GS-15L, 1983.

TYPE=LOWER AQUIFER STATION = GS-15L REPORT YEAR=1983

BASIC AND TRACE WATER QUALITY CONSTITUENTS

| PARAMETER | N | MEAN | STD | MAX | MIN | P5 | P95 |
|---|---|---|---|---|---|---|---|
| PH | 1 | 8.50 | . | 8.50 | 8.50 | 8.50 | 8.50 |
| CONDUCTIVITY | 1 | 2600.00 | . | 2600.00 | 2600.00 | 2600.00 | 2600.00 |
| TOT DIS SOLIDS | 1 | 2322.00 | . | 2322.00 | 2322.00 | 2322.00 | 2322.00 |
| ALKALINITY | 1 | 1411.00 | . | 1411.00 | 1411.00 | 1411.00 | 1411.00 |
| CALCIUM | 1 | 2.40 | . | 2.40 | 2.40 | 2.40 | 2.40 |
| MAGNESIUM | 1 | 35.00 | . | 35.00 | 35.00 | 35.00 | 35.00 |
| POTASSIUM | 1 | 2.40 | . | 2.40 | 2.40 | 2.40 | 2.40 |
| SODIUM | 1 | 700.00 | . | 700.00 | 700.00 | 700.00 | 700.00 |
| BICARBONATE | 1 | 1666.00 | . | 1666.00 | 1666.00 | 1666.00 | 1666.00 |
| CARBONATE | 1 | 0.01 | . | 0.01 | 0.01 | 0.01 | 0.01 |
| CHLORIDE | 1 | 0.51 | . | 0.51 | 0.51 | 0.51 | 0.51 |
| NITRATE | 1 | 0.10 | . | 0.10 | 0.10 | 0.10 | 0.10 |
| SULFATE | 1 | 202.00 | . | 202.00 | 202.00 | 202.00 | 202.00 |
| FLUORIDE | 1 | 5.30 | . | 5.30 | 5.30 | 5.30 | 5.30 |
| AMMONIA | 1 | 1.10 | . | 1.10 | 1.10 | 1.10 | 1.10 |
| PHOSPHATE | 1 | 0.03 | . | 0.03 | 0.03 | 0.03 | 0.03 |
| NITROGEN | 1 | 0.99 | . | 0.99 | 0.99 | 0.99 | 0.99 |
| SILICA | 1 | 5.00 | . | 5.00 | 5.00 | 5.00 | 5.00 |
| IRON | 0 | . | . | . | . | . | . |
| DIS ORG CARBON | 1 | 16.00 | . | 16.00 | 16.00 | 16.00 | 16.00 |
| ARSENIC | 1 | 0.01 | . | 0.01 | 0.01 | 0.01 | 0.01 |
| SELENIUM | 1 | 0.01 | . | 0.01 | 0.01 | 0.01 | 0.01 |
| VANADIUM | 1 | 0.10 | . | 0.10 | 0.10 | 0.10 | 0.10 |
| MOLYBDENUM | 1 | 0.10 | . | 0.10 | 0.10 | 0.10 | 0.10 |
| MERCURY | 1 | 0.30 | . | 0.30 | 0.30 | 0.30 | 0.30 |
| ALUMINUM | 1 | 0.10 | . | 0.10 | 0.10 | 0.10 | 0.10 |
| BARIUM | 1 | 0.10 | . | 0.10 | 0.10 | 0.10 | 0.10 |
| BERYLLIUM | 1 | 0.01 | . | 0.01 | 0.01 | 0.01 | 0.01 |
| BISMUTH | 1 | 0.01 | . | 0.01 | 0.01 | 0.01 | 0.01 |
| BROMIDE | 1 | 0.20 | . | 0.20 | 0.20 | 0.20 | 0.20 |
| CADMIUM | 1 | 1.00 | . | 1.00 | 1.00 | 1.00 | 1.00 |
| CHROMIUM | 1 | 0.01 | . | 0.01 | 0.01 | 0.01 | 0.01 |
| COPPER | 1 | 0.01 | . | 0.01 | 0.01 | 0.01 | 0.01 |
| GALLIUM | 1 | 0.50 | . | 0.50 | 0.50 | 0.50 | 0.50 |
| GERMANIUM | 1 | 0.10 | . | 0.10 | 0.10 | 0.10 | 0.10 |
| LEAD | 1 | 0.01 | . | 0.01 | 0.01 | 0.01 | 0.01 |
| LITHIUM | 1 | 0.25 | . | 0.25 | 0.25 | 0.25 | 0.25 |
| MANGANESE | 1 | 0.05 | . | 0.05 | 0.05 | 0.05 | 0.05 |
| NICKEL | 1 | 0.05 | . | 0.05 | 0.05 | 0.05 | 0.05 |
| STRONTIUM | 1 | 0.07 | . | 0.07 | 0.07 | 0.07 | 0.07 |
| TITANIUM | 1 | 0.50 | . | 0.50 | 0.50 | 0.50 | 0.50 |
| ZINC | 1 | 0.03 | . | 0.03 | 0.03 | 0.03 | 0.03 |
| ZIRCONIUM | 1 | 10.00 | . | 10.00 | 10.00 | 10.00 | 10.00 |

## 5.3 RETORT AND MINE WATER SYSTEMS

During the first five months of 1983, inflow to the mine was fairly stable generally at 900 to 1,100 gallons per minute (Figure 5-11). In early June, flooding in the Corral Gulch drainage resulted in increased inflow to the mine and retort. Mine inflow exceeded 1,700 gallons per minute in August and declined slowly (with additional pumping from dewatering wells starting in October) to under 1,400 gallons per minute at year's end. Inflow to the retorts was less than 15 gallons per minute until June when the inflows began to increase, peaking with an average of nearly 38 gallons per minute in September. Retort inflow then declined to a mean of about 27.5 gallons per minute in December.

Throughout this period, the water elevation in the mine was controlled and held a few feet above that in the retort. Thus the ground water flow direction toward the retort was maintained. Retort leachate was discharged to lined evaporation ponds. Observations of mine and retort water elevations and flows have been reported to the BLM Oil Shale Projects Office and are not duplicated here.

These changes in inflow were reflected in the water quality of leachate pumped from the retort. The temperature of retort leachate increased from about 26°C in May to 49°C in September. This probably resulted from water entering the top portions of the retort which had not cooled appreciably since completion of retorting operations in late 1980.

The fact that water flowed through previously unleached portions of the retort is shown in the specific conductance of the retort leachate (Figure 5-12) which increased from about 4,400 micromhos per cm in May to nearly 7,000 micromhos per cm in July. As this leaching process continued, the conductivity of the leachate has diminished to about 6,000 micromhos per cm at the end of 1983.

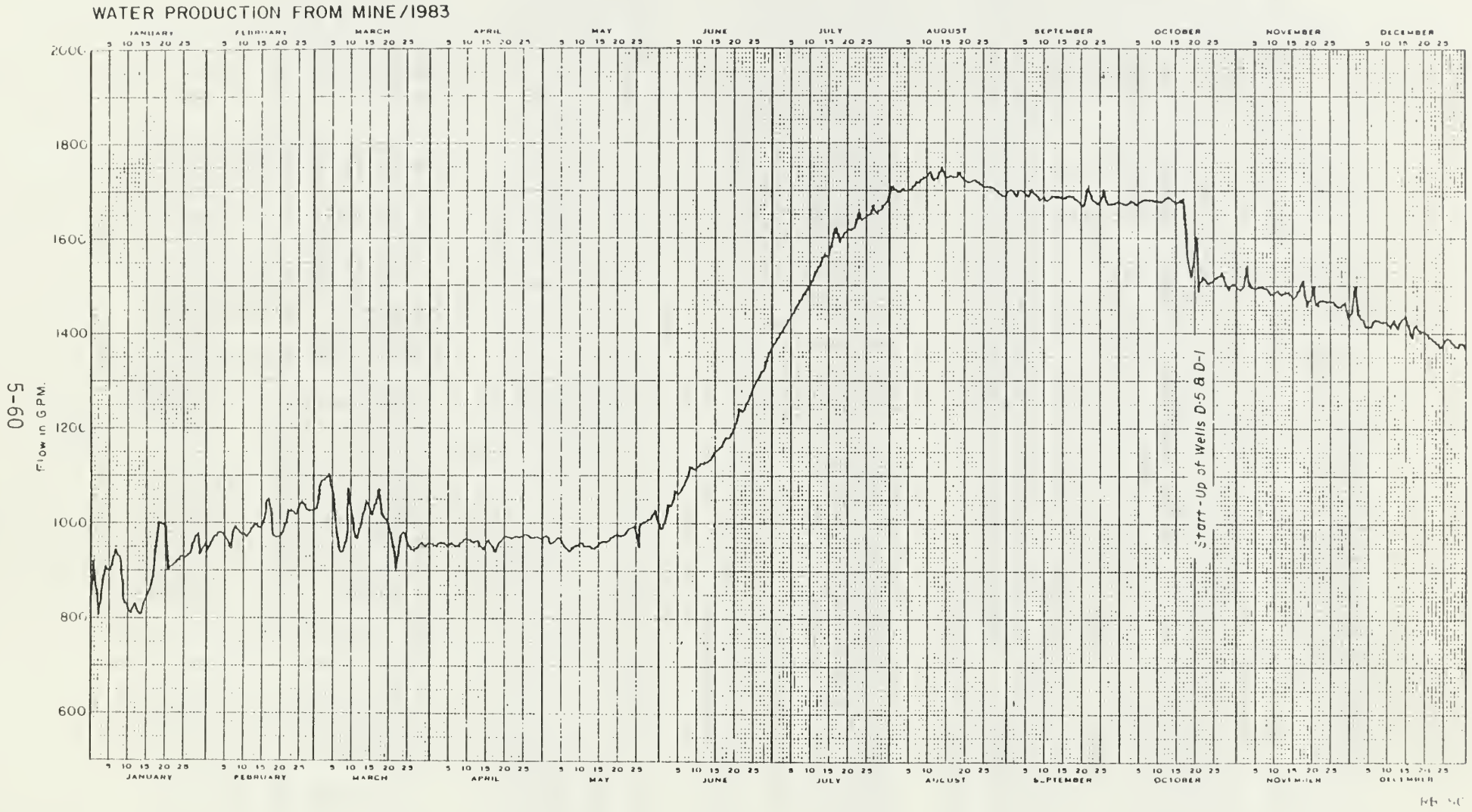



Figure 5-11. Mine Water Inflow (gpm), 1983.

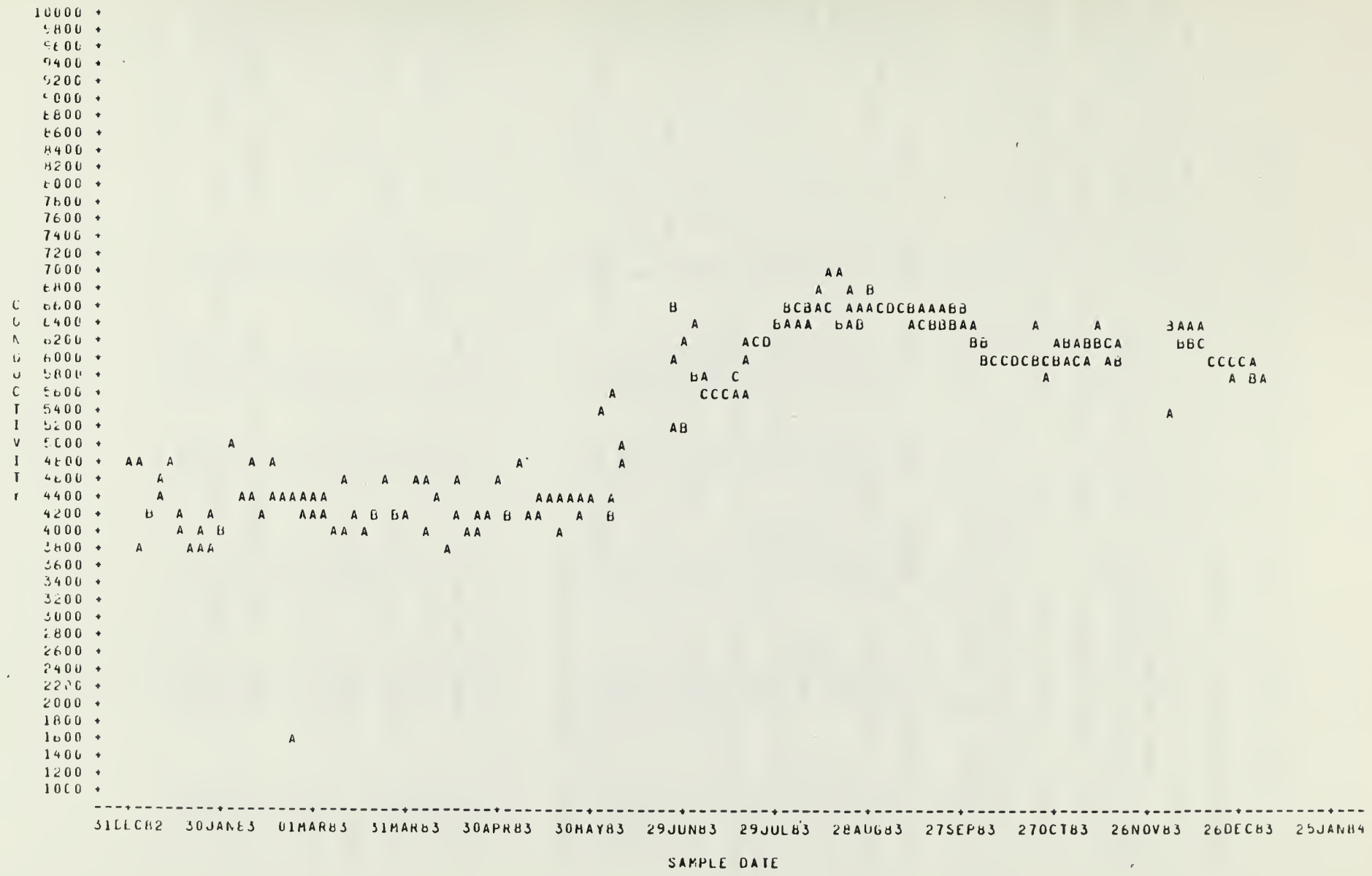



Figure 5-12. Conductivity (micromhos per cm) of Retort Leachate, 1983.

The initial partial flooding of the retort in the fall of 1982 resulted in increased concentration of many dissolved constituents in the retort leachate. These concentrations, having reached their peaks and stabilized during 1982, continued to decrease slowly in early 1983. The subsequent flooding in June 1983 resulted in another increase due to flow of water through previously unleached upper portions of the retort. These increased concentrations moderated toward the end of 1983. Data on selected constituents of the leachate are discussed in the following paragraphs.

The chemistry of the retort leachate during 1983 has been previously reported to the BLM Oil Shale Projects Office. These data are summarized in Table 5-19. Figures 5-13 to 5-19 show the temporal patterns of some major constituents for 1983. Total dissolved solids (TDS) concentration in the leachate followed the pattern described for specific conductance. TDS peaked in August at 6,334 mg/l and declined to less than 5,000 mg/l at the end of 1983 (Figure 5-13). Sodium, potassium and sulfate concentrations (Figures 5-14 and 5-15) follow this same pattern of peak concentrations in August in response to the flooding in June with a slow decline in concentration through the end of 1983. This decline indicates that the retort was partially leached during 1983.

Bicarbonate concentrations appear relatively more stable (than for example sulfate ion concentrations) during 1983 (Figure 5-15). This is largely a reflection of a shift in the bicarbonate - carbonate equilibrium with low carbonate levels in early 1983 and up to 164 mg/l carbonate in September 1983. There was an associated decline in bicarbonate concentration and increase in pH from less than 8 in early 1983 to greater than 8.

Dissolved organic carbon concentrations (Figure 5-16) reached a maximum of 85 mg/l in August 1983 and declined to less than 50 mg/l (comparable to pre-flood concentrations) by the end of the year.

Table 5-19. Summary of Water Chemistry Data for Retort Leachate, 1983.

REPORT YEAR = 1983 STATION = LEACHATE

| PARAMETER | N | MEAN | STD | MAX | MIN | P5 | P95 |
|---|---|---|---|---|---|---|---|
| **BASIC WATER QUALITY PARAMETERS** | | | | | | | |
| CONDUCTIVITY | 16 | 5178.1 | 1202 | 7900.00 | 3900.00 | 3900.0 | 7900.0 |
| TOT. DIS. SOLIDS | 25 | 4655.6 | 1294 | 6334.00 | 1140.00 | 1779.6 | 6332.2 |
| PH | 16 | 7.9 | 0.2 | 8.40 | 7.60 | 7.6 | 8.4 |
| ALKALINITY | 25 | 608.1 | 136.8 | 834.00 | 350.00 | 371.0 | 825.0 |
| CALCIUM | 25 | 60.2 | 21.7 | 110.00 | 34.00 | 34.3 | 107.0 |
| MAGNESIUM | 25 | 45.4 | 19.5 | 92.00 | 16.00 | 16.3 | 83.0 |
| POTASSIUM | 25 | 902.2 | 470.2 | 1600 | 0.57 | 115.6 | 1600.0 |
| SODIUM | 25 | 739.6 | 175.4 | 980.00 | 130.00 | 265.0 | 974.0 |
| CHLORIDE | 25 | 203.4 | 98.4 | 472.00 | 11.20 | 29.0 | 439.9 |
| BICARBONATE | 25 | 611.9 | 179.1 | 829.00 | 273.00 | 291.9 | 822.4 |
| CARBONATE | 25 | 44.4 | 38.8 | 164.00 | 1.00 | 1.0 | 139.1 |
| SULFATES | 25 | 2466.8 | 768.2 | 3514 | 468.00 | 820.8 | 3466.9 |
| SULFIDE | 25 | 113.5 | 59.9 | 256.00 | 0.02 | 0.0 | 246.1 |
| FLOURIDE | 25 | 8.4 | 2.2 | 11.30 | 0.40 | 1.6 | 10.9 |
| AMMONIA | 25 | 23.5 | 13.1 | 54.00 | 0.05 | 2.8 | 53.4 |
| BORON | 25 | 2.9 | 1.4 | 6.10 | 0.27 | 0.5 | 5.9 |
| LITHIUM | 17 | 2.4 | 0.7 | 3.40 | 0.11 | 0.1 | 3.4 |
| MOLYBDENUM | 25 | 0.6 | 0.4 | 1.50 | 0.10 | 0.1 | 1.5 |
| DIS. ORG. CARBON | 25 | 48.8 | 16.8 | 85.00 | 7.00 | 13.6 | 82.9 |
| **TRACE WATER QUALITY PARAMETERS** | | | | | | | |
| ARSENIC | 25 | 0.0 | 0.0 | 0.02 | 0.01 | 0.0 | 0.0 |
| ALUMINUM | 17 | 0.2 | 0.2 | 0.70 | 0.10 | 0.1 | 0.7 |
| BERYLLIUM | 17 | 0.0 | 0.0 | 0.01 | 0.01 | 0.0 | 0.0 |
| CADMIUM | 5 | 0.0 | 0.0 | 0.01 | 0.01 | 0.0 | 0.0 |
| CHROMIUM | 17 | 0.0 | 0.0 | 0.01 | 0.01 | 0.0 | 0.0 |
| COPPER | 17 | 0.0 | 0.0 | 0.01 | 0.01 | 0.0 | 0.0 |
| LEAD | 17 | 0.0 | 0.0 | 0.01 | 0.01 | 0.0 | 0.0 |
| MANGANESE | 17 | 0.0 | 0.0 | 0.03 | 0.01 | 0.0 | 0.0 |
| MERCURY | 25 | 0.3 | 0.1 | 0.70 | 0.30 | 0.3 | 0.6 |
| NICKEL | 17 | 0.0 | 0.0 | 0.05 | 0.05 | 0.0 | 0.0 |
| SELENIUM | 25 | 0.0 | 0.0 | 0.01 | 0.01 | 0.0 | 0.0 |
| STRONTIUM | 17 | 4.7 | 1.1 | 6.30 | 2.91 | 2.9 | 6.3 |
| VANADIUM | 25 | 0.1 | 0.0 | 0.10 | 0.10 | 0.1 | 0.1 |
| ZINC | 17 | 0.1 | 0.3 | 1.40 | 0.01 | 0.0 | 1.4 |

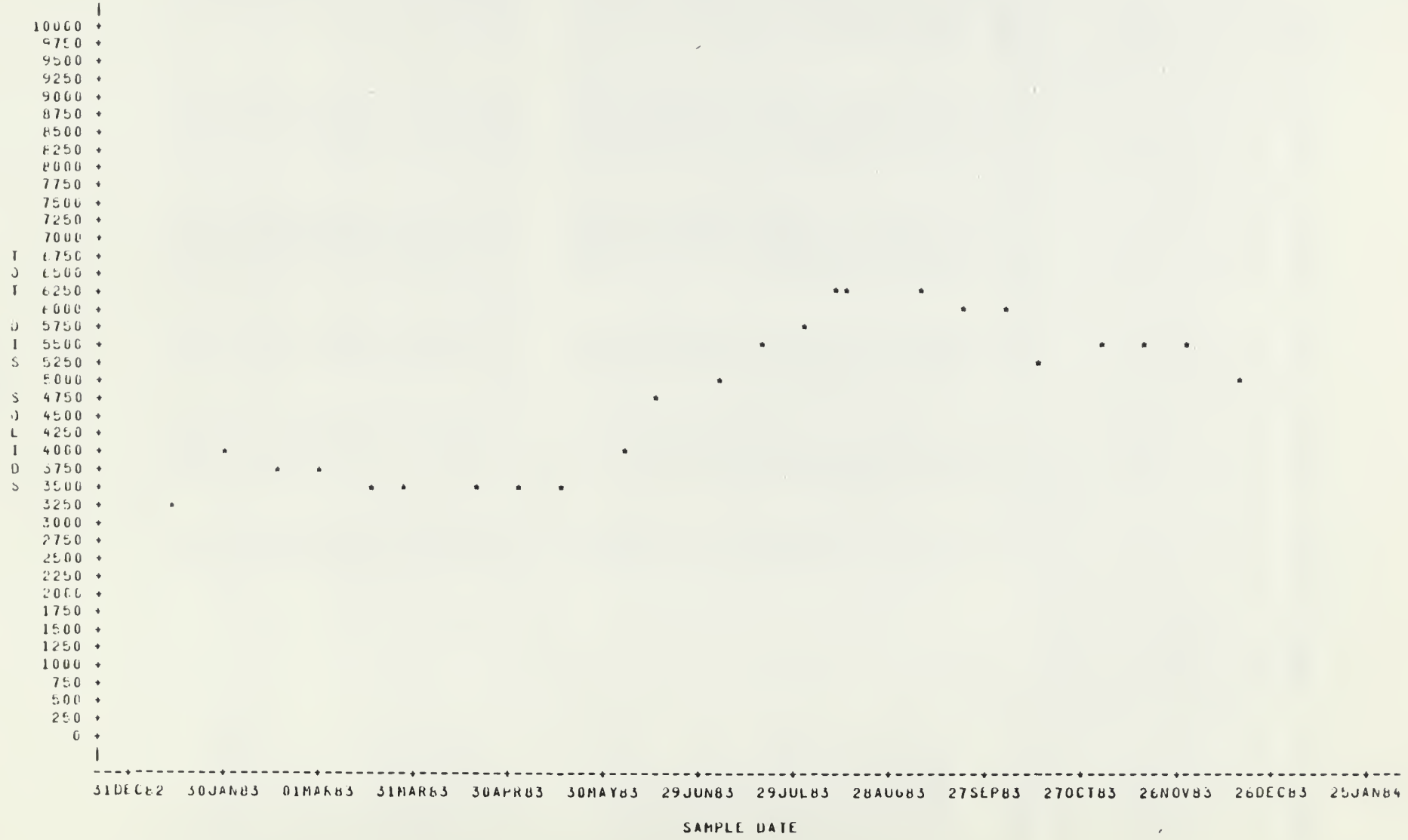



Figure 5-13. Total Dissolved Solids (mg/liter) of Retort Leachate, 1983.

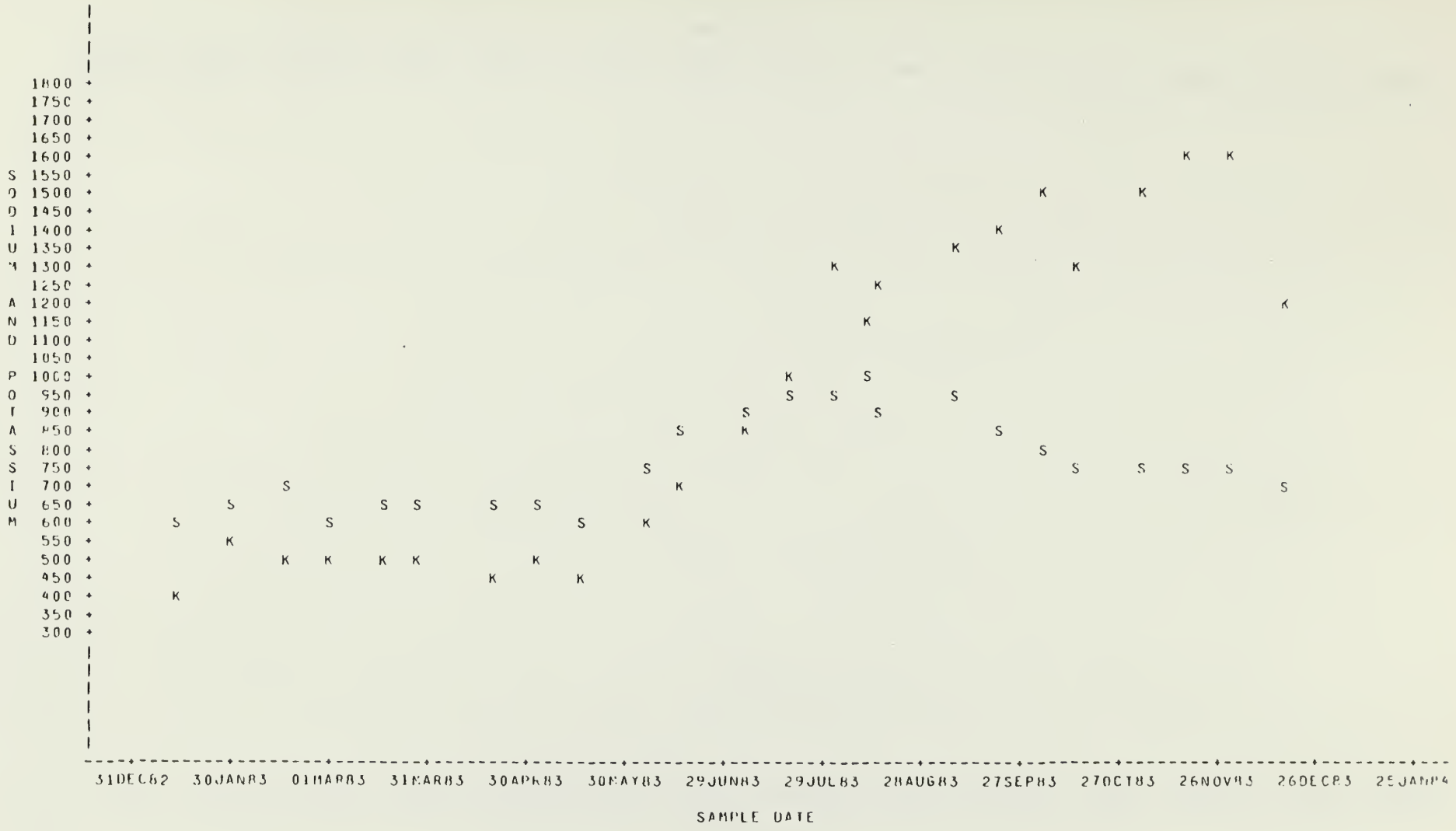



Figure 5-14. Sodium(S) and Potassium(K) (mg/liter) of Retort Leachate, 1983.

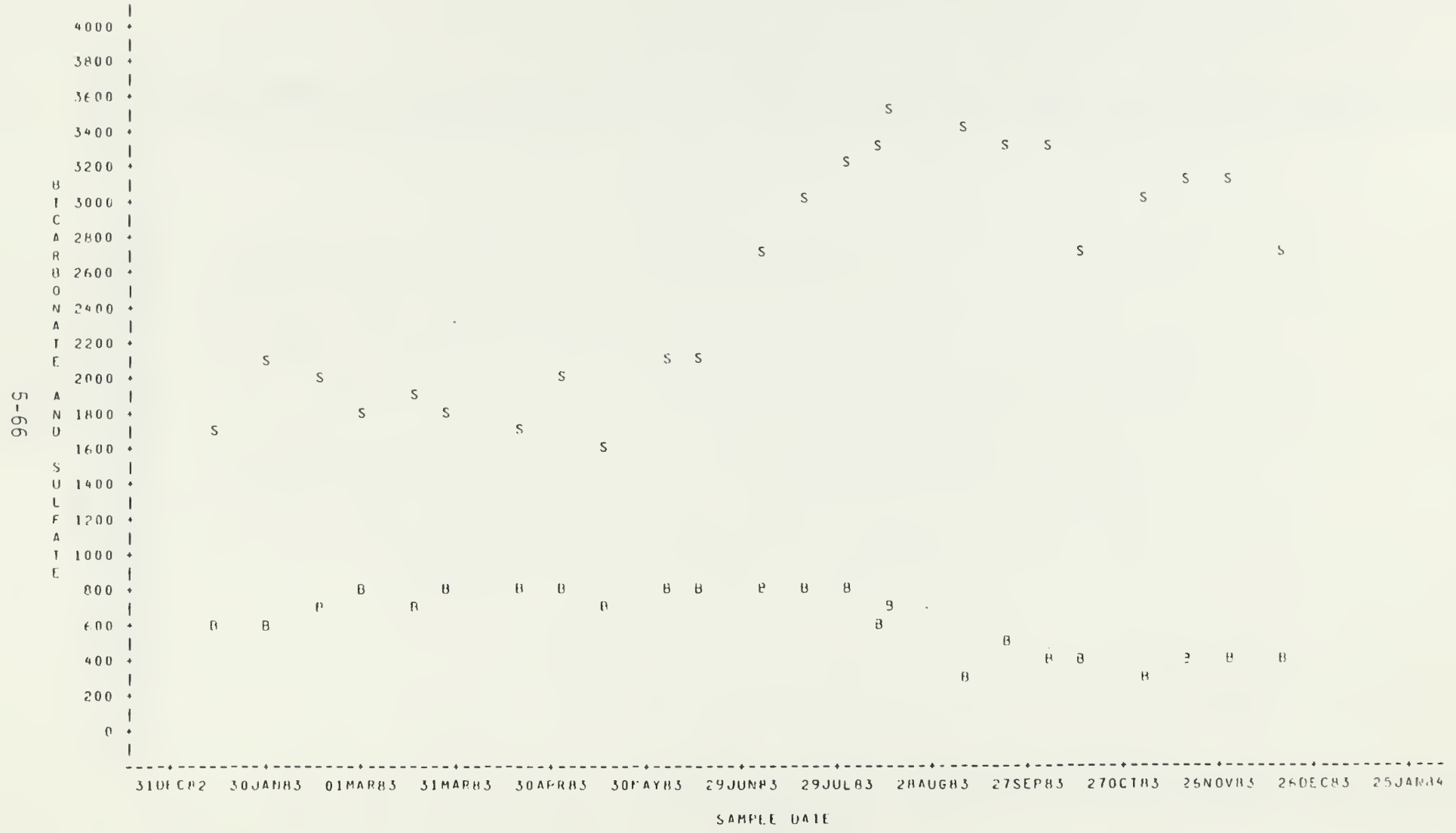





Figure 5-15. Bicarbonate(B) and Sulfate(S) (mg/liter) of Retort Leachate, 1983.

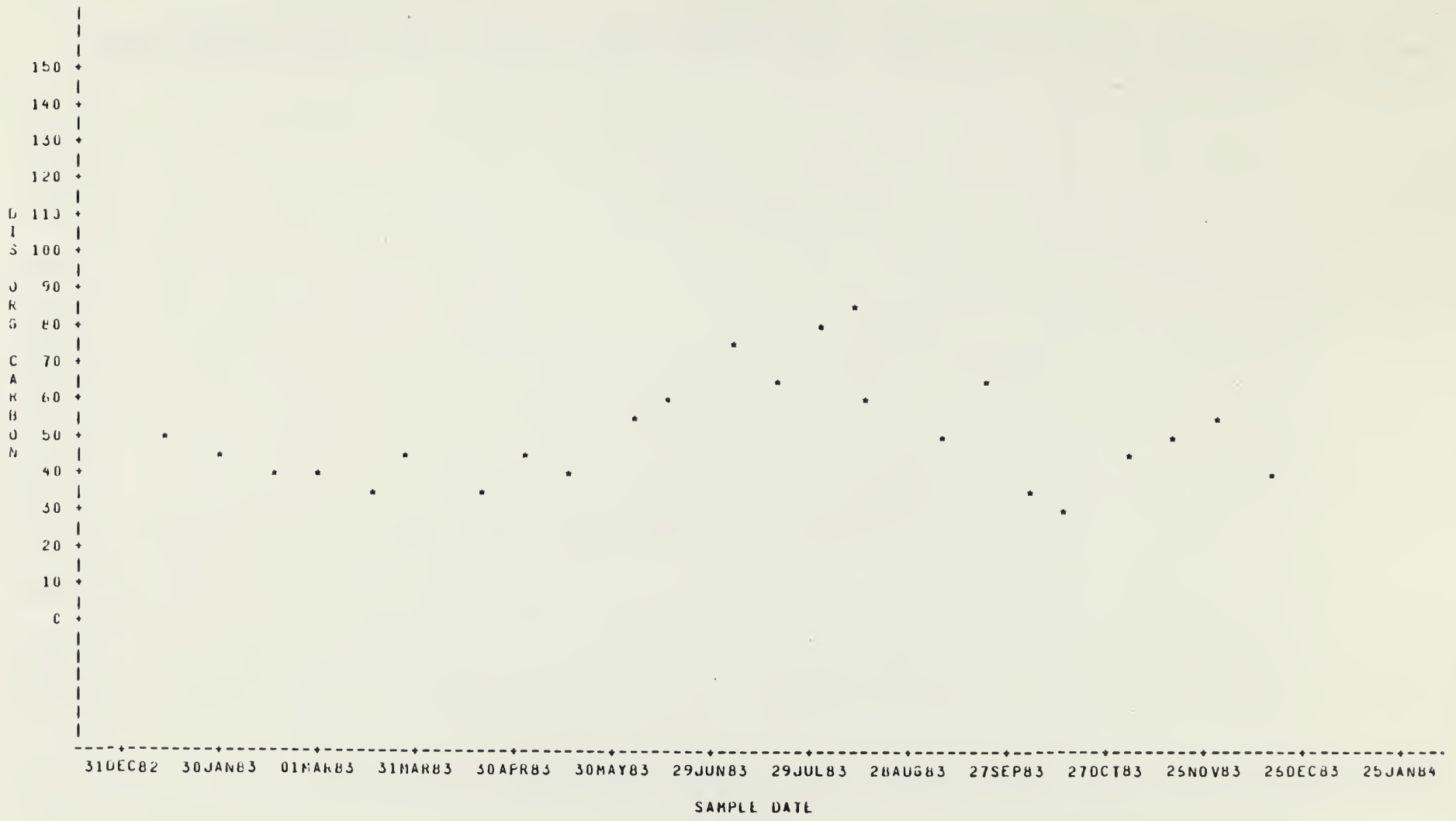





Figure 5-16. Dissolved Organic Carbon (mg/liter) of Retort Leachate, 1983.

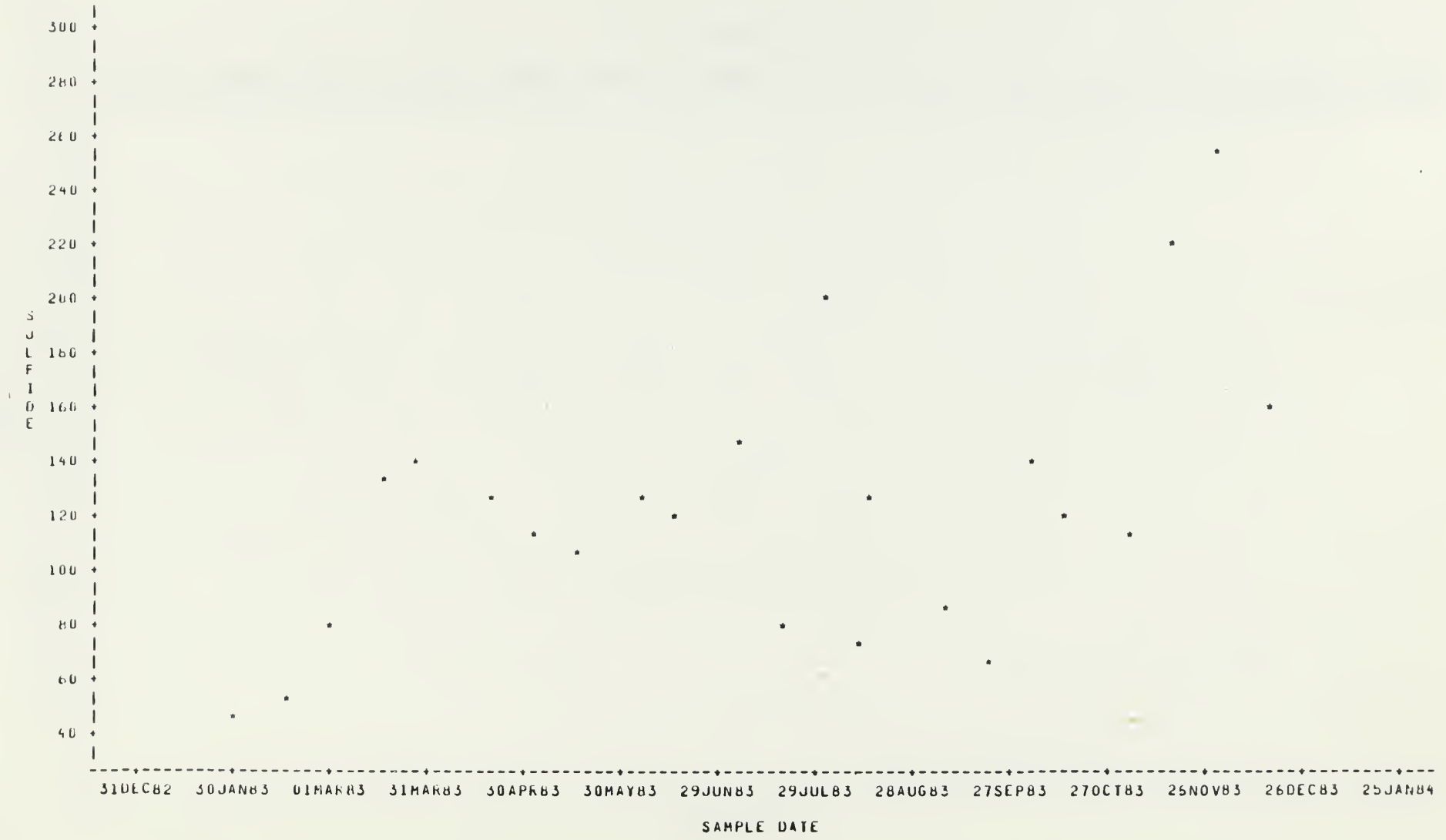



Figure 5-17. Sulfide (mg/liter) of Retort Leachate, 1983.

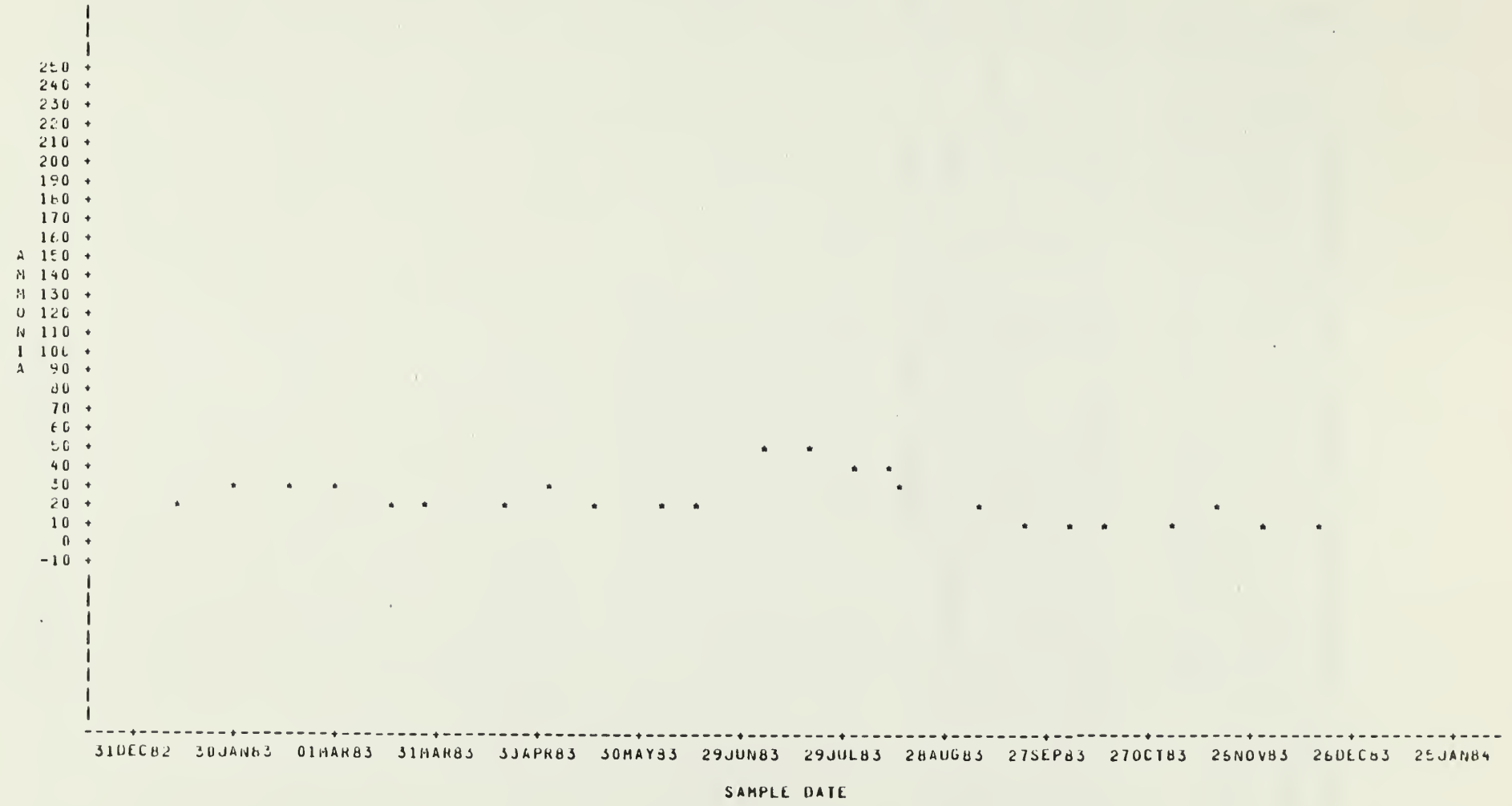



Figure 5-18. Ammonia (mg/liter) of Retort Leachate, 1983.

Figure 5-19. Molybdenum(M) and Boron(B) (mg/liter) of Retort Leachate, 1983.

Sulfide ion concentrations were relatively high throughout 1983 remaining above 100 mg/l for most of the year (Figure 5-17). Ammonia concentrations were approximately 20-30 mg/l in the first half of 1983 (Figure 5-18). Concentrations then increased to over 50 mg/l in July and then declined to usually less than 20 mg/l during the last four months of 1983.

Concentrations of boron in retort leachate were fairly stable at about 2 mg/l in early 1983 (Figure 5-19). After June, concentrations were more variable for several months, ranging from about 1 to 5 mg/l boron while the retort leachate equilibrated following the mid-1983 flooding. Molybdenum concentrations (Figure 5-19) were fairly stable at about 0.5 mg/l and showed no appreciable response to the mid-year flooding.

## 5.4 SUMMARY

The hydrology monitoring program collects information for several needs:

- Stipulations of the lease and conditions of approval from the OSO
- Engineering design input for mine and water handling systems
- Evaluation of the need for environmental mitigative measures
- Permit requirements

The program includes monitoring at numerous installations, including stream gaging stations, springs and seeps, alluvial and deep aquifer wells, surface impoundments, surface discharges, and reinjection system. The natural hydrologic and hydrogeologic environment as well as facilities associated with tract development have been monitored.

During 1983, the hydrology monitoring program focused on three major areas at Tract C-a:

- Dewatering/reinjection/discharge system
- MIS Modular Development area
- Retort and Mine Water Systems

Hydrology monitoring stations have been classified as follows:

- Type I - control stations not expected to be influenced by a given set of development activities

- Type II - expected to exhibit direct, short-term impacts, should impacts result from development; such stations are located generally close to and downgradient in near-field area relative to development

- Type II - expected to exhibit indirect or long-term impacts; should impacts result from development; such stations are located downgradient and realtively distant from development in far-field areas.

Grouping stations allows for spatial as well as temporal comparison of water quality and physical parameters. Thus "pre and post" development levels and the "control vs. potentially affected" areas can be compared.

A. Dewatering/Reinjection/Discharge

During 1983, the dewatering operation was accomplished using mine sumps and dewatering wells, resulting in slight modifications to the cone of depression. All of the 1983 contour lines diminished relative to 1982, indicating a significant filling of the cone of depression.

Total mine water production increased during 1983, from a low of 762 gpm in January to a peak of 1748 gpm in August. Production then decreased and averaged from 1500-1350 gpm towards the end of 1983. Dewatering flows were reinjected or consumed during the entire year.

Water quality of the Jeffrey Pond, which receives mine water, and of the composite reinjection were similar during 1983 and stable throughout the year. The conductivity of both pond and reinjection water was similar to the 1982 data, while the pH was slightly lower. The composite reinjection showed an increase in carbonate and DOC concentrations, while the Jeffrey Pond exhibited a decrease in carbonate. Overall, the water quality of mine water was comparable to observations of previous years.

Field water quality measurements collected at spring sites were not significantly different than previous years. Flow values increased, however, due to heavy snowmelt and precipitation in the spring. The leading edge extended to the White River in July.

Mean water levels increased at upper aquifer wells in all three monitoring areas, due to the heavy snowmelt. Mean conductivity and pH values were essentially the same for control sites between 1983 and 1982. The pH mean was lower than 1982 at the near-field wells, while the conductivity remained stable. The far-field wells showed no appreciable change in pH between 1983 and 1982, while the mean conductivity dropped slightly in 1983. Conductivity was highest and pH lowest in the near-field area.

Water chemistry observations in the upper aquifer control well were generally similar in 1983 to values observed in 1982. Most of the 1983 major water chemistry parameters for near-field wells exceeded the 1982 maximum values. Mean concentrations of calcium, nitrate, and fluoride were slightly higher at far-field wells in 1983 compared to 1982 means. Alkalinity increased from control to the far-field area; sulfate and chloride were in higher concentrations in the near-field and far-field areas. Of the trace elements monitored, only Sr, Li, Br, Cd, and Mn were measurable, but at insignificant levels.

The MANOVA for upper aquifer water chemistry parameters indicated significant variability for most constituents (at $\alpha$ =0.05) in the area main effect, except for pH, fluoride, chloride, and marginally for bicarbonate. Significant variability for the year main effect was exhibited for pH, magnesium, sodium, chloride, and somewhat for fluoride. The interaction term (year x area) was not significant for any of the constituents examined. These results were very similar to the 1982 analyses, indicating a lack of change in water quality at control, near-field, and far-field wells over time.

Using the Duncan's Multiple Range Test, mean concentrations of fluoride, bicarboante, pH, and chloride showed no significant spacial differences. All the constituents examined, except for calcium, exhibited the highest means in the far-field area. The Duncan's analysis for difference among years, showed pH to be the most variable.

The MANOVA analyses, and the Duncan's Multiple Range Test results indicate that, although certain constituents vary significantly in time and space, the general pattern of water quality has not changed appreciably over time. Impact-related changes were not apparent from these analyses.

B. MIS Modular Development Area

This interim monitoring program is designed to continue to detect and evaluate any effects the MIS retorts and surface operations have on deep aquifer, surface waters, and alluvial aquifers. Sites monitored during 1983 included surface streams, springs, alluvial and deep-aquifer wells.

Parameters measured at the spring sites in 1983 were generally comparable to the 1982 data, with the exception of increased flows, due to heavy snowmelt and precipitation in the spring.

Stream station site field data were also comparable to the 1982 data, again with the exception of flow values. Flows increased markedly in late April continuing into August, after extremely heavy runoff and precipitation. Flumes became either silted-in or washed-out, making flow measurements impossible. The highest flow determined prior to this wash-out was 2640.7 gpm at the YMET3 site in April. Conductivity values decreased during this high flow period.

The 1983 water chemistry data from these surface flow stations was very similar to the 1982 data. The concentrations of major water chemistry constituents increased between YMET3 and YSEOFL, as seen in 1982.

MANOVA techniques were used to evaluate temporal variability at these stations, showing few differences for any of the stations.

Using USGS gage station data, the tract area, for the most part, was a net producer of water. This situation was reversed, however, in April and May due to extremely heavy runoff upgradient from the tract. Flows were typically low at the USGS sites until April when flows increased steadily to their peaks in late May. Corral Gulch experienced a mud slide May 31, resulting in a mean flow of 195 cfs at Station D in lower Corral Gulch.

Daily means for all field parameters reported were lowest at Station C (Box Elder Gulch) and highest at Station D (Corral Gulch - East).

Water chemistry parameters analyzed for the USGS stations were comparable to the 1982 analysis. The Duncan's analysis for year main effect showed significant difference for DOC and fluoride. The parameters showing significant variability between stations were sulfate, magnesium, calcium, pH, and conductivity.

Mean water level measurements (depth to water) at alluvial wells during 1983 were less than those observed during 1982, indicating the wet conditions of 1983. Field parameters for all areas were generally comparable to the 1982 data. The pH means showed no variation across the three monitoring areas, while conductivity increased with the downgradient direction.

In general, the water chemistry data collected at alluvial wells in 1983 was comparable to the 1982 data. TDS values, however, were slightly higher in the control and near-field wells. Nitrate was higher in all areas and pH means were slightly lower than seen in 1982.

The results of the MANOVA for alluvial aquifers indicated that the majority of major constituents were significantly variable for the area and year main effects. For most parameters, the near-field water quality was significantly different from the control and far-field areas.

Mean water levels of most upper aquifer wells in all monitoring areas rose during 1983 due to heavy snowmelt and precipitation. Water levels at control and near-field wells remained elevated throughout 1983. The pH means at all monitoring areas showed little change. Conductivity increased at the control wells since 1982, while the near-field and far-field wells remained stable. Conductivity decreased in the down- gradient direction, while pH was lower in the control and near-field wells.

The results of the MANOVA for selected water chemistry constituents of upper aquifer wells indicated that, for most parameters, significant variability was observed in all main effects. For area main effect, all constituents were significantly variable except for sodium, alkalinity, and somewhat for conductivity. Significant temporal variability was noted for all constituents except TDS, and somewhat for conductivity and calcium. All parameters tested exhibited significant variability for the interaction term. These findings were consistent with the 1982 analyses.

Using the Duncan's Multiple Range Test, all three monitoring areas were significantly different for sulfate, calcium, and pH, as seen in 1982. For the year main effect, pH was shown to be the most variable. In general, mean concentrations in recent years have been fairly stable and development-related impacts are not evident.

C. Retort and Mine Water Systems

During the first five months of 1983, inflow to the mine was fairly stable at 900 to 1,100 gallons per minute. Flooding in the spring resulted in an increase in mine inflow until August and then declined slowly to under 1,400 gallons per minute at year's end. Mine water elevation was controlled and held a few feet above that in the retort, maintaining the ground water flow direction toward the retort.

The changes in inflow were reflected in the water quality and chemistry of leachate pumped from the retort. Temperature increases from 26°C in May to 49°C in September were probably due to water entering top portions of the retort which had not cooled since completion of operations. Specific conductance increased from 4,400 micromhos per cm in May to nearly 7,000 micromhos per cm in July. As the leaching process continued, the conductivity has diminished to about 6,000 micromhos per cm at the end of 1983.

This flooding also resulted in increased concentrations of many dissolved constituents in the retort leachate. Total dissolved solids concentrations followed the same pattern as seen with conductivity, along with sodium, potassium, DOC, and sulfate concentrations. Bicarbonate concentrations were relatively more stable throughout the year. Associated with a slight decline in bicarbonate concentration was an increase in carbonate concentration and an increase in pH from less than 8 in early 1983 to greater than 8. Sulfide ion concentrations were relatively high throughout 1983. Ammonia concentrations increased from 20-30 milligrams per liter to over 50 milligrams per liter in July and then declined to less than 20 milligrams per liter by the end of 1983. Concentrations of boron were fairly stable until June when concentrations ranged from 1 to 5 milligrams per liter following the mid-1983 flooding. Molybdenum concentrations were fairly stable and showed no appreciable response to the mid-year flooding.

Throughout this period, water contacting retort materials was discharged to lined evaporation ponds. Interaction with aquifer zones was not observed.

## LITERATURE CITED

Rio Blanco Oil Shale Company. 1981. Modular development phase, monitoring report 7, December 1979 - December 1980. Gulf Oil Corporation and Standard Oil Company (Indiana).

_____. 1983a. Modular development phase, scope of work. Revision 7.0. January 1983. Gulf Oil Corporation and Standard Oil Company (Indiana).

_____. 1983b. Modular development phase, monitoring report 11, January - December 1982. Gulf Oil Corporation and Standard Oil Company (Indiana).

# SECTION 6

# SPECIAL STUDIES
# ECOLOGICAL INTERRELATIONSHIPS

## 6.0 INTRODUCTION

In addition to the monitoring programs which have been reported in the previous sections of this report, RBOSC is conducting special studies in the following areas:

- Experimental Revegetation
- Mule Deer Habitat Modification
- Shrub Growth Enhancement
- Altering Natural Succession after Fire for Enhanced Deer-Livestock Forage
- Comparison of Inhalable and Total Suspended Particulates

The activities during the 1983 reporting year in these areas are included in the Special Studies - Ecological Interrelationships section. The efforts included in this section are designed to examine means of mitigating development-related impacts by examining the relationships between the components of the ecosystems involved. The end result of these studies will be an increased understanding of the feasibility of modifying one ecosystem component (such as vegetative community physical structure and phyto-sociology) to produce a desired effect on another ecosystem component (such as wildlife).

## 6.1 REVEGETATION

### A. Experimental Revegetation on Surface Disturbed Sites

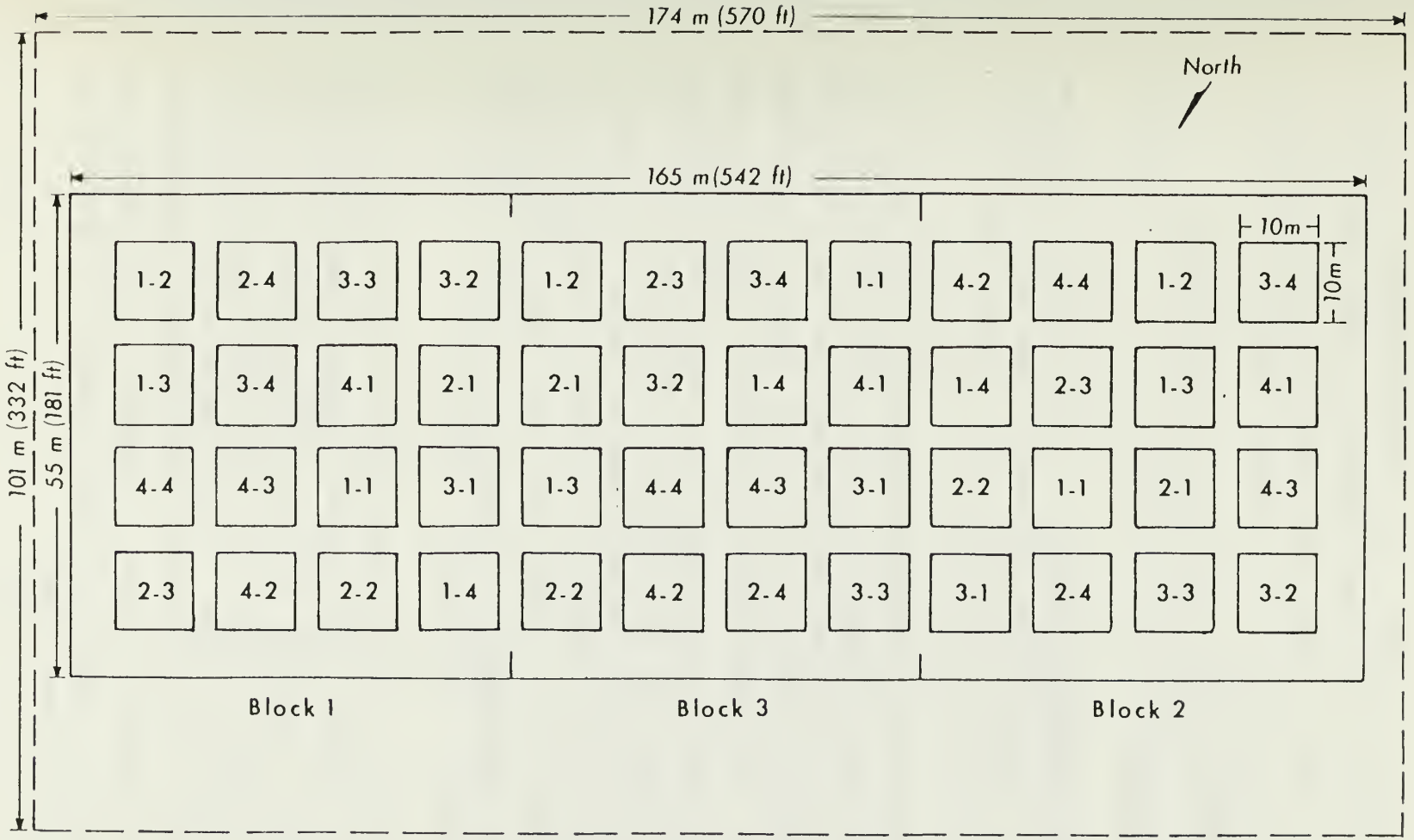
#### 1. Objectives

The development of oil shale facilities on Tract C-a will result in disturbed lands which will be revegetated once disturbance ceases. Experiments were initiated during 1975 to demonstrate reclamation feasibility and species adaptability with varying mulch types, fertilizer applications, and plot aspects.

#### 2. Methods

Experimental plots were constructed at two locations in the southeast corner of Tract C-a; Plot R-1 was located on a northwestern exposure and Plot R-2 was located on a southeastern exposure. Surface disturbance at each site included stripping topsoil and subsoil, ripping the underlying rock substrate, and then replacing the subsoil and topsoil. Subsequent to these activities, the sites were seeded, mulched, and/or fertilized using a total of 16 treatment combinations, with three replicates of each treatment applied at each site in a randomized block design. The configuration for Plot R-1 is illustrated in Figure 6-1. Additional information on methods is presented in Section 2.5.3.2 of Progress Report 4 (RBOSP 1975) and in Revegetation Annual Reports (RBOSC 1977, 1978, 1979).

Cover estimates within each treatment combination on Plots R-1 and R-2 were made within four $m^2$ quadrats (numbered 1-4) during 1976, 1977, 1978, 1980 and 1981. Biomass was determined within each of these same quadrats, in both 1978 and 1981, by clipping and drying the aboveground standing crop after cover estimates were made. Shrub species, however, were not clipped in 1981. In order to assess cover on quadrats undisturbed by previous




Seeding Rate 18 kg/ha (16 lbs/acre)

*Mulch Treatments:*

*(First Numeral in Treatment Designation)*

1=No Mulch
2=Hydromulch
3=Straw Mulch Followed by Crimping
4=Straw Mulch With Netting

*Fertilizer Treatments:*

*(180 kg/ha, 10-5-5)*

*(Second Numeral in Treatment Designation)*

1=No Fertilizer
2=Fertilizer at Time of Sowing
3=Fertilizer at Beginning of First Full Growing Season
4=Fertilizer at Sowing & Beginning of First Full Growing Season

Figure 6-1. Treatment Configuration for Experimental Revegetation Plot R1, Tract C-a.

clipping, four undisturbed quadrats were randomly selected and sampled during 1982 in each of the 16 treatment combinations, within each block on Plots R-1 and R-2. These new quadrats were numbered 5-8, and will serve as the sample locations where cover will be estimated and aboveground biomass determined during subsequent years.

3. Results and Discussion

a. Experimental Revegetation Plot R-1 - Cover estimates for species occurring on Plot R-1 were made July 26-28, 1983. These data are summarized in Table 6-1 and presented in their entirety in Appendix 6-1.1.

Cover for all species over the 16 treatment combinations ranged from 74.5 to 95.1 percent, with a mean of 85.2 percent (Table 6-1). The highest cover value was encountered on plots that had straw mulch held by netting and which were fertilized at sowing as well as at the beginning of the first full growing season. The lowest cover was exhibited on those plots with straw mulch held by crimping and no fertilizer. Mean cover recorded for 1983 increased by 35 percent over that recorded for 1982 (Table 6-2). This increase may be due, in part, to different observers making cover estimates during the two sampling seasons. However, the abnormally high precipitation throughout the growing season in 1983, combined with high overall rainfall in 1982, has likely contributed to increased growth on the revegetation sites as well as elsewhere in the vicinity of Tract C-a.

Cover of herbaceous species on Plot R-1 during 1982 was greater than the 30 to 41 percent cover recorded within "native" sagebrush communities during the same sample season. Shrub cover on Plot R-1 during 1982 was well below that of surrounding sagebrush communities, where shrub cover averaged from 22 to 31 percent (RBSOC 1981, 1982). Direct comparisons with cover in surrounding sagebrush communities for the 1983 season are not available; therefore, it is not possible to test the supposition that increased cover resulting from greater than normal precipitation occurred in these communities as well as on the experimental plots.

TABLE 6-1. MEAN COVER (%) OF PLANTED AND INVADED GRASSES, FORBS, AND SHRUBS FOR EXPERIMENTAL REVEGETATION PLOT R-1 SAMPLED DURING THE CURRENT REPORT YEAR, 1983.

| TREATMENT COMBINATION | GRASSES | | FORBS | | SHRUBS | | TOTAL |
|---|---|---|---|---|---|---|---|
| | PLANTED | INVADED | PLANTED | INVADED | PLANTED | INVADED | COVER |
| NO MULCH NO FERTILIZER | 43.9 | 8.3 | 22.1 | 4.3 | 4.3 | 0.8 | 83.7 |
| NO MULCH FERTILIZER-SOWING | 40.1 | 12.2 | 30.4 | 1.4 | 6.9 | 1.2 | 92.2 |
| NO MULCH FERTILIZER-1ST GROWING | 54.3 | 2.8 | 14.9 | 2.6 | 6.6 | 0.6 | 81.7 |
| NO MULCH FERTILIZER-SOWING/1ST GROWING | 37.8 | 11.7 | 21.3 | 5.4 | 8.5 | 1.1 | 85.7 |
| HYDROMULCH NO FERTILIZER | 34.4 | 1.3 | 34.4 | 4.4 | 4.8 | 0.2 | 79.4 |
| HYDROMULCH FERTILIZER-SOWING | 30.0 | 7.2 | 30.5 | 8.5 | 9.9 | 1.8 | 87.4 |
| HYDROMULCH FERTILIZER-1ST GROWING | 39.1 | 11.0 | 21.7 | 2.8 | 16.3 | 0.3 | 91.2 |
| HYDROMULCH FERTILIZER-SOWING/1ST GROWING | 30.7 | 13.4 | 27.5 | 5.1 | 9.0 | 1.4 | 87.1 |
| STRAW-CRIMPING NO FERTILIZER | 38.3 | 0.6 | 18.8 | 4.9 | 10.9 | 0.9 | 74.5 |
| STRAW-CRIMPING FERTILIZER-SOWING | 38.8 | 3.4 | 30.1 | 6.0 | 7.7 | 0.3 | 86.3 |
| STRAW-CRIMPING FERTILIZER-1ST GROWING | 24.8 | 7.6 | 26.8 | 10.5 | 4.6 | 0.5 | 74.7 |
| STRAW-CRIMPING FERTILIZER-SOWING/1ST GROWING | 45.6 | 8.9 | 14.0 | 4.5 | 4.0 | 0.4 | 77.4 |
| STRAW-NETTING NO FERTILIZER | 57.3 | 4.5 | 24.1 | 1.3 | 5.2 | 1.3 | 93.7 |
| STRAW-NETTING FERTILIZER-SOWING | 50.8 | 10.8 | 19.2 | 3.3 | 6.1 | 0.4 | 90.6 |
| STRAW-NETTING FERTILIZER-1ST GROWING | 50.3 | 4.9 | 22.3 | 2.9 | 2.3 | 0.5 | 83.2 |
| STRAW-NETTING FERTILIZER-SOWING/1ST GROWING | 54.4 | 4.3 | 22.3 | 3.4 | 9.2 | 1.6 | 95.1 |
| MEAN COVER | 41.9 | 7.0 | 23.8 | 4.5 | 7.3 | 0.8 | 85.2 |

Table 6-2. Comparison of Mean Cover (%) Among Years for All Treatment Combinations on Experimental Revegetation Plot R-1, Tract C-a.

| Growth Form | Year | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1976 | 1977 | 1978 | 1980 | 1981 | 1982[1/] | 1983[1/] |
| Grasses Planted | 5.9 | 12.2 | 10.9 | 18.4 | 20.7 | 21.3 | 41.9 |
| Grasses Invaded | 2.5 | 0.1 | 0.5 | 3.4 | 3.5 | 4.1 | 7.0 |
| Forbs Planted | 3.6 | 4.1 | 1.7 | 9.8 | 10.6 | 16.1 | 23.8 |
| Forbs Invaded | 10.2 | 23.4 | 20.9 | 6.0 | 4.5 | 3.4 | 4.5 |
| Shrubs Planted | 2.1 | 3.3 | 3.7 | 3.0 | 2.7 | 4.4 | 7.3 |
| Shrubs Invaded | 0.0 | 0.0 | 0.1 | 0.1 | 0.8 | 0.4 | 0.8 |
| TOTAL | 24.5 | 43.1 | 37.8 | 40.7 | 42.8 | 49.8 | 85.2 |

1/ Data are based on cover estimates from sample quadrats established in 1982.

Planted grasses averaged 41.9 percent cover during 1983 and accounted for 49.2 percent of the total cover averaged over all treatment combinations. Invader grasses averaged 7.0 percent cover and accounted for 8.2 percent of total mean cover. When compared to the 1982 data, this represents nearly a doubling of cover for planted grasses and a 6 percent increase in planted grass cover as a proportion of total cover. The proportion of cover attributable to invader grasses remained the same for both 1982 and 1983. Although perennial grasses might be expected to respond rapidly to increased moisture, the increase in cover noted for 1983 seems inordinately large and may be due in part to sampling error as well as increased precipitation.

The proportional cover between treatment combinations on Plot R-1 remained essentially the same as for 1982. Highest cover of planted grasses was recorded on areas receiving straw mulch held by netting and no fertilizer. Lowest cover was noted on areas where straw mulch was crimped and fertilizer applied at the beginning of the first growing season (Table 6-1). The dominant planted grasses continued to be the wheatgrass (Agropyron) species. Green needlegrass (Stipa viridula) and Indian ricegrass (Oryzopsis hymenoides), though encountered frequently, contributed lower percentages of cover than did the wheatgrasses. Cheatgrass (Bromus tectorum) and squirreltail (Sitanion hystrix) were the main contributors to cover of invader grasses (Appendix 6-1.1).

A statistical comparison of 1983 cover data for planted or invader grasses between treatment combinations revealed no significant first or second order interactions, and only one significant main effect (Table 6-3). Results of a Duncan's Multiple Range Test comparing four mulch treatments illustrated that, although most mulch treatments had similar cover, invader grasses on no mulch treatments had significantly higher cover than on sites with straw mulch held in place by crimping (Appendix 6-1.2). This relationship has not been noted in analyses from recent years and it is unclear why it becomes evident in these data.

Table 6-3. Results of Three-way ANOVA's Comparing Arcsine Transformed Grass, Forb, and Shrub Cover Estimates for Planted and Invaded Species Among Treatment Combinations During 1983 on Experimental Revegetation Plot R-1, Tract C-a.[1/]

| Growth Form | Source of Variation | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Block | | Mulch | | Fertilizer | | Block x Mulch | | Block x Fertilizer | | Mulch x Fertilizer | | Block x Mulch x Fertilizer | |
| | F | PR>F[2/] | F | PR>F[2/] | F | PR>F[2/] | F | PR>F[2/] | F | PR>F[2/] | F | PR>F[2/] | F | PR>F[2/] |
| Grasses Planted | 0.17 | 0.8450 | 1.65 | 0.1802 | 0.01 | 0.9962 | 0.05 | 0.9994 | 0.29 | 0.9427 | 0.19 | 0.9944 | 0.11 | 1.0000 |
| Grasses Invaded | 1.79 | 0.1736 | 2.86* | 0.0420 | 2.49 | 0.0658 | 0.58 | 0.7490 | 0.88 | 0.5164 | 0.84 | 0.5806 | 0.41 | 0.9745 |
| Forbs Planted | 1.08 | 0.3417 | 1.07 | 0.3651 | 1.12 | 0.3430 | 1.13 | 0.3488 | 0.40 | 0.8783 | 0.61 | 0.7891 | 1.26 | 0.2257 |
| Forbs Invaded | 0.74 | 0.4792 | 0.81 | 0.4924 | 1.22 | 0.3035 | 0.26 | 0.9527 | 0.47 | 0.8307 | 1.45 | 0.1697 | 0.63 | 0.8675 |
| Shrubs Planted | 0.90 | 0.4083 | 0.85 | 0.4700 | 0.27 | 0.8462 | 0.40 | 0.8764 | 1.11 | 0.3639 | 1.18 | 0.3192 | 0.56 | 0.9166 |
| Shrubs Invaded[3/] | | | | | | | | | | | | | | |

* Significant at $\alpha = 0.05$

** Significant at $\alpha = 0.025$

1/ Duncan's Multiple Range Test results for significant main effects are presented in Appendix 6-1.2.

2/ Represents the significance probability ($\alpha$) associated with F.

3/ Missing values occur when there is insufficient data to produce ANOVA results

When data from all years are included in a similar comparison, variations in cover of planted grasses on mulch treatments and invader grasses on fertilizer treatments appear to be significant (Table 6-4). Duncan's Multiple Range Test results using data from all years illustrate that cover of invader grasses is significantly higher on plots fertilized both at sowing and at the beginning of the first growing season than on those which received no fertilizer. Although most mulch treatments appear to be similar, the two straw mulch treatments differ, with higher cover of planted grasses noted on plots where straw was held in place by netting (Appendix 6-1.2). Results of analyses using 1983 data versus those using data from all years seem somewhat contradictory regarding the influence of mulch and/or fertilizer. Nevertheless, the effects of these cultural amendments can be expected to be most evident during the first several years after planting.

Because of the marked increase in cover for 1983, it is not surprising that significant differences in cover of both planted and invader grasses were noted in statistical comparisons among years without regard to treatments (Table 6-5). Results of Duncan's Multiple Range Tests (Appendix 6-1.2) indicate that cover of planted grasses during 1983 was significantly higher than for all other years. Although cover increased each of the previous three years, there were no significant differences within the 1980-1982 period. Relationships among years for invader grasses were not nearly as definitive, with cover for 1983 being similar to all years except 1977 and 1978 (Appendix 6-1.2).

Cover of planted forbs (23.8 percent) during 1983 accounted for 28 percent of the total mean cover for all treatment combinations (Table 6-1). Even though cover increased from the 16.1 percent recorded in 1982, the proportion of planted forbs to all vegetation cover decreased slightly, probably because of the disproportionate increase in grasses (Table 6-2). Invader forb species also increased in cover, from 3.4 in 1982 to 4.5 percent in 1983. As a proportion of total mean cover, this increase also

Table 6-4. Results of Three-way ANOVA's Comparing Arcsine Transformed Grass, Forb, and Shrub Cover Estimates for Planted and Invaded Species Among Treatment Combinations for All Sample Periods (1977, 1978, 1980, 1981, 1982 and 1983) on Experimental Revegetation Plot R-1, Tract C-a.[1/]

| Growth Form | Source of Variation | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Block | | Mulch | | Fertilizer | | Block x Mulch | | Block x Fertilizer | | Mulch x Fertilizer | | Block x Mulch x Fertilizer | |
| | F | PR>F[2/] | F | PR>F[2/] | F | PR>F[2/] | F | PR>F[2/] | F | PR>F[2/] | F | PR>F[2/] | F | PR>F[2/] |
| Grasses Planted | 0.70 | 0.4966 | 3.41** | 0.0170 | 1.11 | 0.3460 | 0.24 | 0.9637 | 0.76 | 0.6012 | 0.51 | 0.8700 | 0.38 | 0.9913 |
| Grasses Invaded | 1.64 | 0.1947 | 1.09 | 0.3552 | 3.30** | 0.0203 | 2.05 | 0.0582 | 1.86 | 0.0868 | 1.19 | 0.2991 | 1.03 | 0.4263 |
| Forbs Planted | 4.63** | 0.0099 | 3.81** | 0.0100 | 2.86* | 0.0356 | 1.76 | 0.1039 | 0.57 | 0.7571 | 1.69 | 0.0870 | 1.49 | 0.0863 |
| Forbs Invaded | 0.86 | 0.4235 | 2.37 | 0.0675 | 2.03 | 0.1066 | 0.44 | 0.8527 | 1.02 | 0.4120 | 0.92 | 0.5034 | 0.81 | 0.6956 |
| Shrubs Planted | 0.14 | 0.8685 | 9.95** | 0.0001 | 0.84 | 0.4745 | 0.24 | 0.9630 | 2.97** | 0.0070 | 3.25** | 0.0007 | 0.95 | 0.5109 |
| Shrubs Invaded | 1.66 | 0.1978 | 0.84 | 0.4807 | 4.98** | 0.0039 | 3.65** | 0.0037 | 1.47 | 0.2019 | 2.02 | 0.0515 | 2.56** | 0.0044 |

* Significant at $\alpha = 0.05$

** Significant at $\alpha = 0.025$

1/ Duncan's Multiple Range Test results for significant main effects are presented in Appendix 6-1.2.

2/ Represents the significance probability ($\alpha$) associated with F.

Table 6-5. Results of One-way ANOVA's Comparing Arcsine Transformed Cover Estimates for Grasses, Forbs, and Shrubs Between 1976, 1977, 1978, 1980, 1981, 1982 and 1983 for Experimental Revegetation Plot R-1, Tract C-a[1/]

| Growth Form | Source of Variation Year | |
|---|---|---|
| | F | PR>F[2/] |
| Grasses Planted | 56.20** | 0.0001 |
| Grasses Invaded | 7.35** | 0.0001 |
| Forbs Planted | 64.10** | 0.0001 |
| Forbs Invaded | 39.47** | 0.0001 |
| Shrubs Planted | 28.98** | 0.0001 |
| Shrubs Invaded | 1.44 | 0.2263 |

** Significant at $\alpha = 0.025$

1/ Duncan's Multiple Range Test results for significant main effects are presented in Appendix 6-1.2.

2/ Represents the significance probabiity ($\alpha$) associated with F.

represented a slight decrease from the 1982 position. It would appear that grasses on Plot R-1 are better able to translate increased moisture into growth than are the forbs.

The distribution of forb cover among the various treatment combinations changed very little in 1983 relative to that reported in 1982. Highest cover of planted species, primarily cicer milkvetch (Astragalus cicer var Lutana), Lewis flax (Linum lewisii), and yellow sweetclover (Melilotus officinalis var Madrid), remained on plots which had been hydromulched and which received no fertilizer (Table 6-1). The highest cover of invader forbs was found in areas with crimped straw mulch and where fertilizer had been applied at the beginning of the first growing season. No single invader forb species approached the cover of planted species; however, Scarlet gilia (Ipomopsis aggregata), Douglas chaenactis (Chaenactis douglasii), and Machaeranthera species continued to be frequent minor contributors to cover (Appendix 6-1.1).

In spite of the variations in cover among treatment combinations as noted on Table 6-1, statistical comparisons for 1983 data showed no significant differences based on either the main or interaction effects tested (Table 6-2). During 1982, differences had been evident among blocks as well as mulch treatments. However, when data from all years are compared, significant variations among main effects are still evident (Table 6-4). Planted forb species in Block 2 (Figure 6-1) contribute significantly more cover over all years than they do in Blocks 1 or 3. Furthermore, some minor influences of both mulch and fertilizer appear to be evident (Appendix 6-1.2). Because these differences are not evident in analyses using only 1983 data, it can be assumed that differences are becoming less evident with time.

When forb cover was compared among years without regard to treatment combinations, cover of planted forb species was significantly higher in 1983 than for any other sample period (Table 6-5; Appendix 6-1.2). A similar circumstance was evident in 1982. This increase may be due in large part to

increased growth of cicer milkvetch, which seems to be able to compete favorably with the grasses on this site. Invader forb species for 1983 exhibited cover similar to that recorded during 1980-1982. With the increased cover of planted grasses, forbs and shrubs continuing, invasion of species from the surrounding plant communities will be slow.

Cover of planted shrub species increased from 4.4 percent in 1982 to 7.3 percent in 1983. As a proportion of total mean cover on Plot R-1, cover during 1983 was about the same as evidenced in 1982 (8.6 vs. 8.8, respectively). Cover of invader shrub species increased from 0.4 in 1982 to 0.8 percent in 1983, which is identical to the cover recorded in 1981 (Table 6-2). Broom snakeweed (Gutierrezia sarothrae) continued to be the only invader species encountered, whereas big sagebrush (Artemisia tridentata), winterfat (Ceratoides lanata), and rubber rabbitbrush (Chrysothamnus nauseosus) were relatively common planted species. The general distribution of shrub cover among treatment combinations was the same as recorded in 1982.

Although no significant differences among treatments were noted for shrub cover during 1983 (Table 6-3), when data from all years were analyzed, a number of significant differences continued to be evident, as indicated on Table 6-4. Results of Duncan's Multiple Range Tests show that planted shrub species seem to be favored by either hydromulch or no mulch treatments over either of the straw mulch treatments. The relationship of invader shrub species is somewhat less clear, perhaps due in part to the paucity of data. There is some indication that broom snakeweed, the only invader species encountered, is favored by hydromulch over the crimped straw or no mulch treatments.

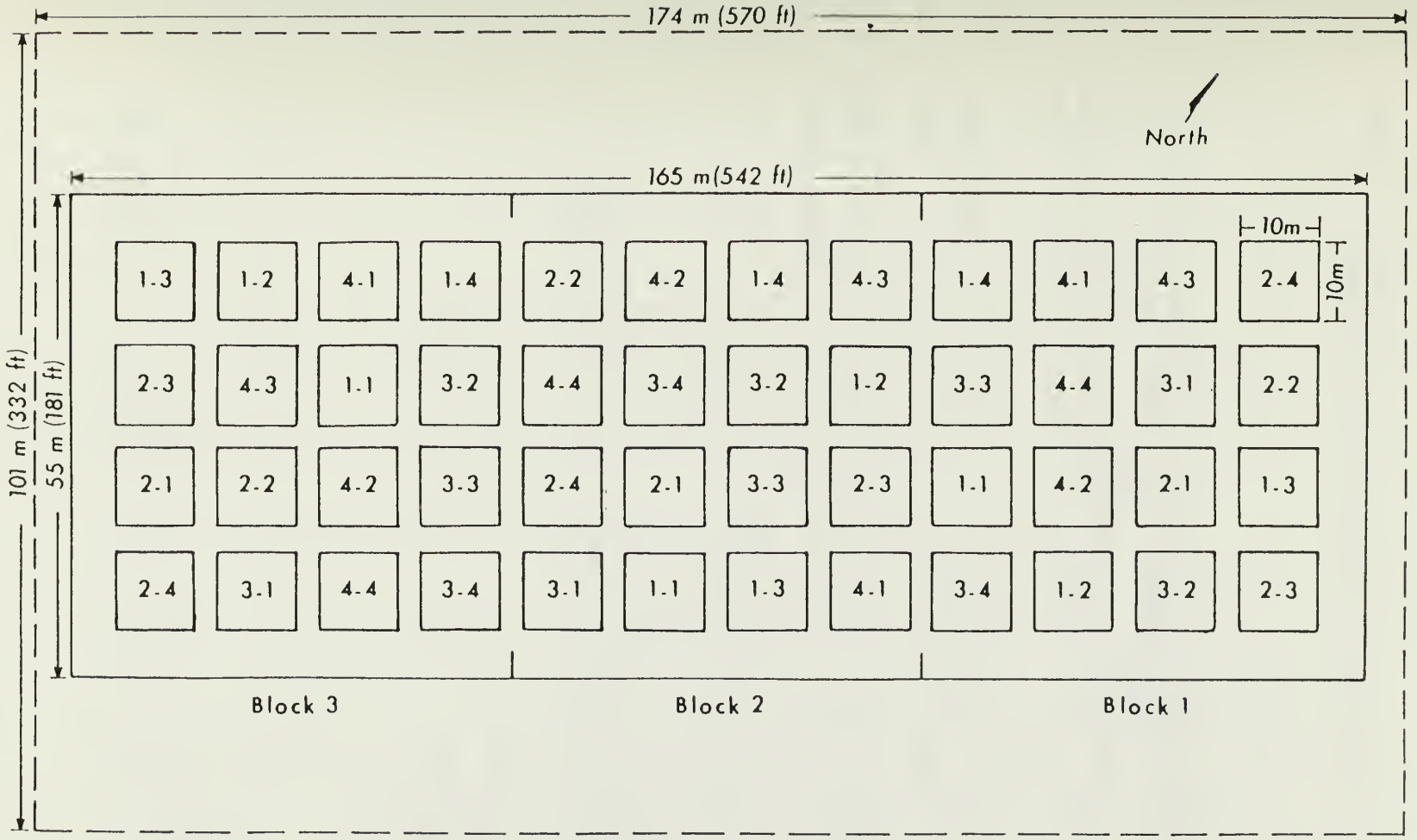
Significant differences in cover of planted shrub species occur among years when analyses are run without regard to treatment combinations (Table 6-5). Cover during 1983 was shown to be significantly higher than for the other six years of record (Appendix 6-1.2). Consequently, data indicate that shrubs, as well as grasses and forbs, have apparently responded to increased precipitation.

b. Experimental Revegetation Plot R-2 - Cover estimates for species occurring on Plot R-2 were made July 14 and 23-26, 1983. The Plot R-2 configuration is illustrated on Figure 6-2. Data collected during 1983 are summarized on Table 6-6 and are presented in their entirety in Appendix 6-1.3.

Cover for all species over the 16 treatment combinations ranged from 49.5 to 74.9 percent, with a mean of 62.0 percent (Table 6-6). The trend in cover among treatment combinations changed slightly from that recorded in 1982. Highest cover was encountered on plots which received straw mulch held in place by crimping and which were fertilized at the time of sowing. The lowest cover was noted where the mulch treatment was identical to that noted above but where fertilization occurred at the beginning of the first growing season. Mean cover over all treatment plots during 1983 (62.0 percent) increased from the 38.6 percent average cover noted during 1982 (Table 6-7). Although it is reasonable to assume that much of this increase resulted from growth associated with increased precipitation, a portion of the increase may also be attributable to sampling error (see discussion related to Plot R-1).

The increased cover noted for R-2 during 1983 relative to 1982 was somewhat less than the corresponding increase noted for R-1. It is likely that the variation is associated with higher evapotranspiration, hence reduced plant available moisture, on the southerly exposure of R-2 relative to the northerly exposure of R-1. The cover of herbaceous species on Plot R-2 during 1983 was 42.1 percent, a value equal to the 30-41 percent cover found in "native" sagebrush communities during previous years. As noted for Plot R-1, direct comparisons with "native" communities are not available for the 1983 sample period.

Cover of planted grasses averaged 21.8 percent during 1983 and accounted for 35 percent of total cover averaged over all treatment combinations. Invader




Seeding Rate 18 kg/ha (16 lbs/acre)

*Mulch Treatments:*

*(First Numeral in Treatment Designation)*

1=No Mulch
2=Hydromulch
3=Straw Mulch Followed by Crimping
4=Straw Mulch With Netting

*Fertilizer Treatments:*

*(180 kg/ha, 10-5-5)*

*(Second Numeral in Treatment Designation)*

1=No Fertilizer
2=Fertilizer at Time of Sowing
3=Fertilizer at Beginning of First Full Growing Season
4=Fertilizer at Sowing & Beginning of First Full Growing Season

Figure 6-2. Treatment Configuration for Experimental Revegetation Plot R2, Tract C-a.

TABLE 6-6. MEAN COVER (%) OF PLANTED AND INVADED GRASSES, FORBS, AND SHRUBS FOR EXPERIMENTAL REVEGETATION PLOT R-2 SAMPLED DURING THE CURRENT REPORT YEAR, 1983.

| TREATMENT COMBINATION | GRASSES PLANTED | GRASSES INVADED | FORBS PLANTED | FORBS INVADED | SHRUBS PLANTED | SHRUBS INVADED | TOTAL COVER |
|---|---|---|---|---|---|---|---|
| NO MULCH NO FERTILIZER | 20.0 | 1.4 | 18.5 | 3.3 | 13.7 | 0.8 | 57.6 |
| NO MULCH FERTILIZER-SOWING | 21.8 | 4.4 | 18.1 | 2.3 | 16.0 | 0.2 | 62.7 |
| NO MULCH FERTILIZER-1ST GROWING | 17.3 | 1.8 | 9.9 | 3.5 | 17.3 | . | 49.8 |
| NO MULCH FERTILIZER-SOWING/1ST GROWING | 16.7 | 3.8 | 8.8 | 2.6 | 26.7 | . | 58.5 |
| HYDROMULCH NO FERTILIZER | 18.4 | 0.6 | 6.8 | 0.8 | 27.1 | 3.5 | 57.1 |
| HYDROMULCH FERTILIZER-SOWING | 19.1 | 2.0 | 12.3 | 2.2 | 27.3 | 0.2 | 63.0 |
| HYDROMULCH FERTILIZER-1ST GROWING | 16.9 | 5.9 | 11.6 | 2.3 | 22.2 | 1.3 | 60.2 |
| HYDROMULCH FERTILIZER-SOWING/1ST GROWING | 19.9 | 5.3 | 17.5 | 3.3 | 13.8 | 0.6 | 60.2 |
| STRAW-CRIMPING NO FERTILIZER | 21.8 | 0.3 | 28.1 | 1.3 | 15.9 | 3.3 | 70.7 |
| STRAW-CRIMPING FERTILIZER-SOWING | 26.2 | 1.6 | 20.1 | 2.0 | 21.4 | 3.7 | 74.9 |
| STRAW-CRIMPING FERTILIZER-1ST GROWING | 18.8 | 2.4 | 9.9 | 2.9 | 13.9 | 1.7 | 49.5 |
| STRAW-CRIMPING FERTILIZER-SOWING/1ST GROWING | 24.5 | 1.9 | 20.3 | 1.8 | 16.9 | 0.6 | 65.9 |
| STRAW-NETTING NO FERTILIZER | 29.4 | 2.8 | 17.3 | 0.8 | 20.3 | 1.3 | 71.8 |
| STRAW-NETTING FERTILIZER-SOWING | 26.5 | 2.6 | 22.3 | 1.4 | 13.1 | 0.4 | 66.3 |
| STRAW-NETTING FERTILIZER-1ST GROWING | 22.1 | 4.1 | 5.3 | 3.4 | 18.6 | 1.0 | 54.5 |
| STRAW-NETTING FERTILIZER-SOWING/1ST GROWING | 29.5 | 3.2 | 15.3 | 1.9 | 18.6 | 0.7 | 69.1 |
| MEAN COVER | 21.8 | 2.7 | 15.1 | 2.2 | 18.9 | 1.2 | 62.0 |

Table 6-7. Comparison of Mean Cover (%) Among Years for All Treatment Combinations on Experimental Revegetation Plot R-2, Tract C-a.

| Growth Form | Year | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1976 | 1977 | 1978 | 1980 | 1981 | 1982[1/] | 1983[1/] |
| Grasses Planted | 4.6 | 9.0 | 8.1 | 15.1 | 11.5 | 14.0 | 21.8 |
| Grasses Invaded | 2.6 | 0.1 | 0.4 | 0.8 | 1.3 | 1.6 | 2.7 |
| Forbs Planted | 2.8 | 3.3 | 2.5 | 8.3 | 7.3 | 9.8 | 15.1 |
| Forbs Invaded | 5.6 | 21.1 | 12.9 | 6.8 | 3.6 | 1.9 | 2.2 |
| Shrubs Planted | 1.4 | 2.6 | 4.7 | 6.2 | 5.6 | 10.5 | 18.9 |
| Shrubs Invaded | 0.0 | 0.0 | 0.0 | 0.1 | 0.4 | 0.8 | 1.2 |
| TOTAL | 17.0 | 36.1 | 28.5 | 37.3 | 29.7 | 38.6 | 62.0 |

1/ Data are based on cover estimates from sample quadrats established in 1982.

grasses averaged 2.7 percent cover, or approximately four percent of all cover. Although increases in cover of both planted and invader species were substantial in 1983 as compared to 1982, the proportion of total mean cover attributable to both categories remained essentially the same. Highest cover was noted on areas which received straw mulch held in place by netting but which received no fertilizer. The same treatment combination had the greatest cover in 1982 as well. Lowest cover of planted species was encountered on areas fertilized both at sowing and at the beginning of the first full growing season, but which received no mulch. Wheatgrass species and Indian ricegrass were the most frequently encountered planted grasses. Strangely enough, both highest and lowest cover of invaded species, primarily crested wheatgrass (Agropyron cristatum), squirreltail and needle-and-thread (Stipa comata), occurred among hydromulched treatments, but with varying fertilizer applications (Table 6-6). As noted in previous reports, the differences among treatments noted this long after application of the mulch and/or fertilizer are likely not directly related to the amendments, but rather are artifacts of the study design and/or related to competition among species which began within several years after planting.

A statistical comparison of 1983 cover data for planted or invader grasses between treatment combinations revealed only one significant main effect difference (Table 6-8). Duncan's Multiple Range Test results indicate that cover of invader grasses was signficantly higher in Block 1 (See Figure 6-2) than in either of the other two block replications (Appendix 6-1.4). This was not evident during 1982 and it is unclear why the difference becomes evident in the 1983 data.

When data for all years from R-2 are lumped together and analyzed using a three-way ANOVA, variations among blocks become evident for both planted and invader species (Table 6-9). In these instances there is an inverse relationship between planted and invader species. Cover of invader species in Block 1 remains higher than that in the other blocks, as noted above for 1983 data, whereas planted species in Block 1 contribute significantly lower cover (Appendix 6-1.4). Regardless of what brought about the low cover of

Table 6-8. Results of Three-way ANOVA's Comparing Arcsine Transformed Grass, Forb, and Shrub Cover Estimates for Planted and Invaded Species Among Treatment Combinations During 1983 on Experimental Revegetation Plot R-1, Tract C-a.[1/]

| Growth Form | Source of Variation | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Block | | Mulch | | Fertilizer | | Block x Mulch | | Block x Fertilizer | | Mulch x Fertilizer | | Block x Mulch x Fertilizer | |
| | F | PR>F[2/] | F | PR>F[2/] | F | PR>F[2/] | F | PR>F[2/] | F | PR>F[2/] | F | PR>F[2/] | F | PR>F[2/] |
| Grasses Planted | 2.26 | 0.1087 | 1.01 | 0.3902 | 0.57 | 0.6401 | 0.44 | 0.8479 | 0.42 | 0.8649 | 0.20 | 0.9928 | 0.51 | 0.9509 |
| Grasses Invaded | 4.21* | 0.0090 | 0.82 | 0.4981 | 0.19 | 0.9012 | 0.94 | 0.4774 | 0.10 | 0.9956 | 0.27 | 0.9760 | 0.44 | 0.9194 |
| Forbs Planted | 0.04 | 0.9577 | 1.09 | 0.3574 | 1.56 | 0.2053 | 0.54 | 0.7787 | 0.59 | 0.7347 | 0.42 | 0.9226 | 0.41 | 0.9809 |
| Forbs Invaded | 1.39 | 0.2554 | 0.05 | 0.9784 | 0.73 | 0.5428 | 0.69 | 0.6609 | 1.98 | 0.0781 | 0.92 | 0.5098 | 0.49 | 0.9522 |
| Shrubs Planted | 2.03 | 0.1392 | 0.45 | 0.7250 | 0.12 | 0.9417 | 0.58 | 0.7418 | 0.33 | 0.9189 | 0.44 | 0.9116 | 0.36 | 0.9916 |
| Shrubs Invaded[3/] | | | | | | | | | | | | | | |



* Significant at $\alpha = 0.05$

** Significant at $\alpha = 0.025$

1/ Duncan's Multiple Range Test results for significant main effects are presented in Appendix 6-1.4.

2/ Represents the significance probability ($\alpha$) associated with F.

3/ Missing values occur when there is insufficient data to produce ANOVA results

Table 6-9. Results of Three-way ANOVA's Comparing Arcsine Transformed Grass, Forb, and Shrub Cover Estimates for Planted and Invaded Species Among Treatment Combinations For all Sample Periods (1977, 1978, 1980, 1981, 1982 and 1983) on Experimental Revegetation Plot R-2, Tract C-a.[1/]

| Growth Form | Source of Variation | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Block | | Mulch | | Fertilizer | | Block x Mulch | | Block x Fertilizer | | Mulch x Fertilizer | | Block x Mulch x Fertilizer | |
| | F | PR>F[2/] | F | PR>F[2/] | F | PR>F[2/] | F | PR>F[2/] | F | PR>F[2/] | F | PR>F[2/] | F | PR>F[2/] |
| Grasses Planted | 4.32** | 0.0136 | 1.16 | 0.3223 | 0.28 | 0.8424 | 0.68 | 0.6635 | 0.90 | 0.4909 | 0.31 | 0.9697 | 0.73 | 0.7862 |
| Grasses Invaded | 6.88** | 0.0012 | 1.57 | 0.1959 | 0.23 | 0.8740 | 1.64 | 0.1353 | 0.49 | 0.8159 | 0.51 | 0.8663 | 0.43 | 0.9801 |
| Forbs Planted | 0.45 | 0.6349 | 1.89 | 0.1279 | 2.02 | 0.1072 | 2.08 | 0.0536 | 0.96 | 0.4488 | 1.04 | 0.4074 | 1.25 | 0.2154 |
| Forbs Invaded | 2.76 | 0.0636 | 4.73** | 0.0030 | 2.60* | 0.0499 | 0.63 | 0.7095 | 0.52 | 0.7916 | 0.82 | 0.6009 | 0.26 | 0.9992 |
| Shrubs Planted | 2.80 | 0.0614 | 4.89** | 0.0024 | 0.59 | 0.6229 | 2.76** | 0.0115 | 0.65 | 0.6903 | 1.19 | 0.2994 | 0.41 | 0.9853 |
| Shrubs Invaded | 16.46** | 0.0001 | 1.82 | 0.1613 | 2.12 | 0.1152 | 1.75 | 0.1387 | 1.13 | 0.3640 | 2.00 | 0.0687 | 1.15 | 0.3587 |

* Significant at $\alpha = 0.05$

** Significant at $\alpha = 0.025$

1/ Duncan's Multiple Range Test results for significant main effects are presented in Appendix 6-1.2.

2/ Represents the significance probability ( $\alpha$ ) associated with F.

planted species, it is reasonable to assume that the continued reduced competition from planted species has favored invaders.

Comparison of cover among years without regard to treatment combinations shows that significant differences exist for both planted and invader species (Table 6-10). Duncan's Multiple Range Tests on these differences indicate that cover of invader grasses during 1983 was higher than for all years except 1976. Planted grass species were shown to have cover higher than all other sample periods (Appendix 6-1.4).

Cover of planted forb species on Plot R-2 averaged 15.1 percent during 1983, which accounted for 24 percent of the average cover over all treatments (Table 6-6). This represents an increase in cover relative to 1982 (Table 6-7), but a slight decrease in the proportion which planted forbs contributed relative to all species. Invader forb species increased only slightly relative to 1982 (2.2 vs. 1.9 percent). As noted during 1982, highest cover of planted species (28.1 percent) was encountered on areas which were not fertilized and which received hay mulch held by crimping. The highest cover of invader species changed slightly from that noted during 1982. Areas which received no mulch but which were fertilized at the begining of the first growing season had the highest cover, with three other treatment combinations having similar but slightly lower cover. Cicer milkvetch and Lewis flax continue to be the most prevalent planted forb species encountered. Yellow sweetclover and Utah sweetvetch (Hedysarum utahensis) were fairly common but contributed low cover relative to the flax and milkvetch (Apendix 6-1.3). There was little change, if any, in the composition of invader species, Douglas chaenactis, cryptantha (Cryptantha sericia), Machaeranthera and lobeleaf groundsel (Senecio multilobatus) being the most common species.

Results of the three-way ANOVA comparing 1983 forb cover among treatment combinations show no significant main or interaction effects (Table 6-8). However, when data from all years are combined and analyzed with the same three-way ANOVA, significant main effect differences in cover of invader

forbs are evident for both mulch and fertilizer (Table 6-9). Because similar differences are not evident for 1983 data alone, it can be assumed that variations in cover which occurred in previous years are the primary contributors to these significant differences. These results support the supposition that cultural amendments such as mulch and fertilizer impart their benefits during the years shortly after application. Although cover of invader forb species was similar for most mulch treatments, cover was significantly lower for hydromulch treatments than for either the no mulch or netted straw mulch. Cover of invader forb species was also similar for most fertilizer regimes. However, cover was significantly lower for no fertilizer than for the multiple fertilizer application (Appendix 6-1.4).

Comparisons of forb cover among years using a one-way ANOVA indicated that significant differences exist for both planted and invader species (Table 6-10). Duncan's Multiple Range Test results show that cover of planted species during 1983 was significantly higher than for all other sample periods (Appendix 6-1.4). Cover of invader species, on the other hand, was similar to all other years except 1977 and 1978, when cover of invaders was significantly higher. High cover of planted species during 1983 may be related in increased moisture during the growing season.

Shrub cover for planted species averaged 18.9 percent over all treatment combinations during the 1983 sample period, with the range being from 13.1 to 27.3 percent (Table 6-6). Cover of planted shrub species accounts for 30 percent of total mean cover for all species. Cover of invaders species averaged 1.2 percent during 1983, with a range of zero to 3.7 percent.

Areas which received hydromulch and fertilizer at the time of sowing supported the highest cover of planted shrubs, while the lowest cover was encountered on areas which were mulched with straw held in place by netting and which were fertilized at the time of sowing (Table 6-6). This represents as shift in cover relative to that recorded during 1982, however the change is more likely related to sampling error than to a cause-and-effect

Table 6-10. Results of One-way ANOVA's Comparing Arcsine Transformed Cover Estimates for Grasses, Forbs, and Shrubs Between 1976, 1977, 1978, 1980, 1981, 1982 and 1983 for Experimental Revegetation Plot R-2, Tract C-a[1/]

| Growth Form | Source of Variation Year | |
|---|---|---|
| | F | PR>F[2/] |
| Grasses Planted | 56.29** | 0.0001 |
| Grasses Invaded | 12.84** | 0.0001 |
| Forbs Planted | 47.78** | 0.0001 |
| Forbs Invaded | 44.27** | 0.0001 |
| Shrubs Planted | 47.84** | 0.0001 |
| Shrubs Invaded | 2.25 | 0.0890 |

** Significant at $\alpha = 0.025$

1/ Duncan's Multiple Range Test results for significant main effects are presented in Appendix 6-1.2.

2/ Represents the significance probability ($\alpha$) associated with F.

relationship with mulch and/or fertilizer. No change in highest versus lowest cover among treatment combinations was noted for invader shrub species in 1983 relative to 1982. Rubber rabbitbrush was the greatest contributor to cover of planted shrub species, with winterfat, fourwing saltbrush (Atriplex canescens) and antelope bitterbrush (Purshia tridentata) being somewhat less common and contributing lower cover. Broom snakeweed was the only invader shrub species encountered on Plot R-2.

A statistical comparison of cover of planted shrubs among the various treatment combinations for 1983 indicated no significant main or interaction effects (Table 6-8). Nevertheless, when data for all years were considered, one significant first order interaction and one significant main effect were noted (Table 6-9). Differences for invader shrub species were limited to the main effect associated with replication of treatment blocks. Results of Duncan's Multiple Range Tests indicate that Block 1 has higher cover of invader shrubs than the other blocks. Possible explanations for this phenomenon were discussed in MDP Monitoring Report 11 (RBOSC 1983). Variations in cover of planted shrub species based on mulch treatments were also subjected to a Duncan's Multiple Range Test. Significantly higher cover of planted shrubs is found on hydromulched areas as compared to either of the straw mulch treatments (Appendix 6-1.4).

c. Precipitation - Average rainfall totalled 10.8 inches (27.4 cm) on Plot R-1 and 11.0 inches (27.9 cm) on Plot R-2 for the April-October 1983 recording period (Table 6-16, Section 6.1B). These precipitation totals were the highest recorded during eight years of measurements at the two locations. Although precipitation for 1982 was also higher than for previous years, there was one important difference between 1982 and 1983 precipitation regimes. Reduced precipitation during the June-July period on Tract C-a has been the norm during much of the RBOSC period of record. In 1982 this general pattern continued, although the monthly totals for both June and July increased relative to previous years. However, the rainfall totals for 1983 showed essentially none of the typical decrease in precipitation during June and July relative to the other months of the

growing season.

The more uniform rainfall throughout the growing season seems to have resulted in increased growth of grasses, forbs and shrubs on the experimental revegetation plots. Cool season grasses such as those planted in the revegetation plots tend to have their greatest photosynthetic activity during the spring and fall periods. This bimodal growth cycle corresponds to periods of relatively high rainfall on Tract C-a. However, with more uniform precipitation, growth appears to have been maintained and/or accelerated throughout the growing season, resulting in increased vegetative cover.

B. Experimental Revegetation on a Simulated Processed Shale Disposal Site

1. Objectives

During RBOSC's demonstration of surface retorting technology and subsequent commercial operations, processed shale will be produced as a by-product of surface retorting. This material will require surface disposal because not all of the processed shale can be returned as a slurry to in-situ retorts and/or returned to an open pit mine. RBOSC initiated revegetation experiments in 1976 to determine a feasible method of reestablishing a productive, self-sustaining livestock and/or wildlife habitat on processed shale disposal sites.

2. Methods

Revegetation Plot R-3 was established in the fall of 1976, and is located near the southeastern corner of Tract C-a. The plot is situated in an area with a southeast-facing aspect and a slope of approximately 20 percent.

The plot is designed to simulate an artificial soil profile for use in overburden/processed shale disposal piles. This profile, from bottom to top, consists of 0.45 m of compacted Tosco II processed shale, 0.9 m of

segregated sized overburden-like material, 0.3 m of subsoil, and 0.15 m of topsoil. The overburden-like material (0.9 m) is expected to inhibit the capillary migration of soluble, potentially toxic components from the processed shale into the surface plant growth medium. The treatment configuration at Plot R-3 is designed to test the effectiveness of this reconstructed soil profile, as well as various seeding rates and mulch regimes (Figure 6-3). Portions of Plot R-3 underlain by processed shale are considered treatments while those without processed shale serve as controls.

During 1983 cover was assessed within three 1 $m^2$ quadrats within each of the 36 treatment plots. These sample quadrats were the same as those randomly selected and sampled during 1982.

Soil moisture samples (percent volume) were collected in 1983 from three depths (approximately 25 cm, 75 cm and 150 cm) within permanently established holes centered above each of 36 plots on R-3. Soil moisture samples were obtained monthly from May - October using a Troxler neutron probe depth moisture gauge. Gauge readings were corrected for the non-water hydrogen component of the reading using correction factors determined at the time access tubes were established in 1982. Continued use of these correction factors is based on the assumption that hydrogen associated with such things as organics remains relatively constant.

Additional information on experimental revegetation Plot R-3 is available in MDP Monitoring Report 5 (RBOSC 1980) and in Revegetation Annual Reports (RBOSC 1977, 1978, 1979).

## 3. Results and Discussion

a. Cover Data - Cover for grasses, forbs, and shrubs on Plot R-3 was estimated July 11-13, 1983. These data are summarized on Table 6-11 and presented in their entirety in Appendix 6-1.5.

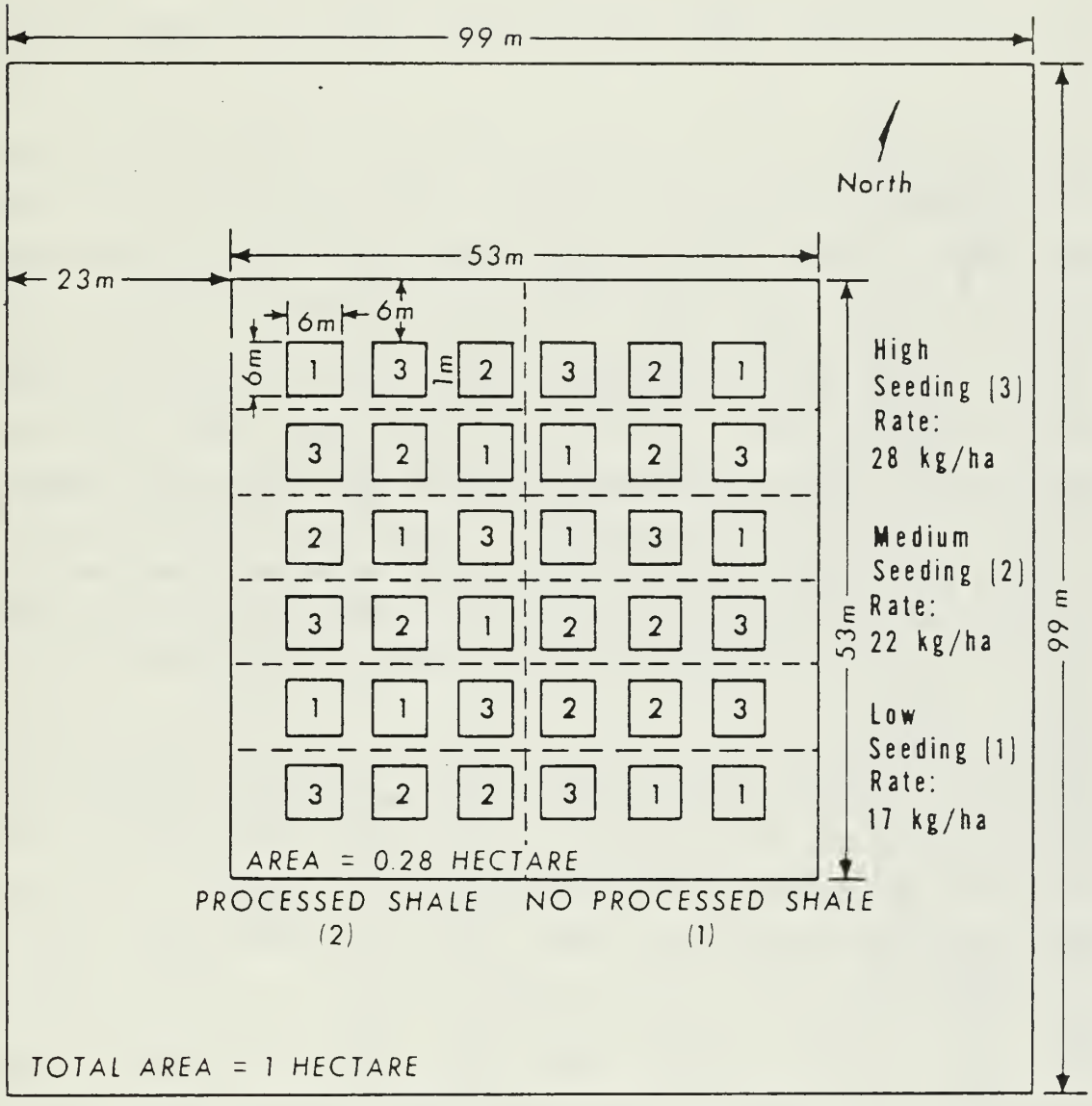



Figure 6-3. Configuration of Experimental Revegetation Plot over 'Tosco II' Processed Shale.

TABLE 6-11. COVERAGE (%) OF PLANTED AND INVADED GRASSES, FORBS, AND SHRUBS FOR EXPERIMENTAL REVEGETATION PLOT R-3 (SUBPLOTS 4, 5, AND 6) DURING THE CURRENT REPORTING YEAR, 1983

| TREATMENTS COMBINATIONS | CONTROL (NO PROCESSED SHALE) | | | | | | | TREATMENT (PROCESSED SHALE) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | GRASSES | | FORBS | | SHRUBS | | TOTAL | GRASSES | | FORBS | | SHRUBS | | TOTAL |
| | PLANTED | INVADED | PLANTED | INVADED | PLANTED | INVADED | COVER | PLANTED | INVADED | PLANTED | INVADED | PLANTED | INVADED | COVER |
| HAY MULCH LOW SEEDING | 22.5 | 18.5 | 5.3 | 1.0 | 21.3 | . | 68.7 | 29.5 | 17.3 | 6.0 | . | 14.2 | . | 67.0 |
| HYDROMULCH LOW SEEDING | 24.8 | 12.5 | 16.5 | . | 6.8 | 2.0 | 62.7 | 17.3 | 7.0 | 12.2 | 0.2 | 21.5 | 1.3 | 59.5 |
| NO MULCH LOW SEEDING | 24.8 | 8.2 | 8.7 | . | 16.5 | 0.3 | 58.5 | 33.7 | 7.5 | 10.5 | . | 5.5 | 0.3 | 57.5 |
| HAY MULCH MEDIUM SEEDING | 21.8 | 22.7 | 11.7 | . | 7.0 | 0.2 | 63.3 | 27.8 | 11.8 | 8.3 | . | 14.8 | . | 62.8 |
| HYDROMULCH MEDIUM SEEDING | 25.5 | 9.2 | 8.0 | 0.2 | 18.0 | 6.8 | 67.7 | 23.7 | 8.8 | 16.2 | 1.2 | 24.7 | 0.2 | 74.7 |
| NO MULCH MEDIUM SEEDING | 27.7 | 13.0 | 9.7 | 0.7 | 12.0 | 2.3 | 65.3 | 23.8 | 10.7 | 15.7 | 0.2 | 13.0 | 0.3 | 63.7 |
| HAY MULCH HIGH SEEDING | 26.2 | 13.3 | 12.2 | 1.5 | 14.3 | . | 67.5 | 25.3 | 12.7 | 3.3 | 0.3 | 20.7 | 0.7 | 63.0 |
| HYDROMULCH HIGH SEEDING | 32.0 | 6.0 | 18.0 | 0.2 | 11.7 | . | 67.8 | 29.2 | 2.5 | 14.5 | 0.3 | 26.2 | . | 72.7 |
| NO MULCH HIGH SEEDING | 27.5 | 2.8 | 9.0 | . | 12.5 | . | 51.8 | 25.5 | 3.3 | 3.8 | 1.5 | 28.7 | . | 62.8 |
| MEAN COVER | 25.9 | 11.8 | 11.0 | 0.4 | 13.4 | 1.3 | 63.7 | 26.2 | 9.1 | 10.1 | 0.4 | 18.8 | 0.3 | 64.9 |

Cover for all species averaged 63.7 percent on the control (no processed shale) portion of R-3, with the range being from 51.8 to 68.7 percent. Average cover on the treatment (underlain by processed shale) portion of R-3 was 64.9 percent, with the range being from 57.5 to 74.7 percent (Table 6-11).

Highest and lowest total cover determinations for the treatment (processed shale) portion of the site were encountered on the same treatment combinations as noted in 1982 (hydromulch-medium seeding and no mulch-low seeding, respectively). The distribution of total cover on the control (no shale) portion of the site changed relative to 1982, with highest cover being encountered on hay mulch-low seeding combinations and the lowest cover on no mulch-high seeding combinations. Cover of all species averaged over all treatment combinations has increased from 43.5 percent in 1982 to 64.3 percent in 1983 (Table 6-12). As discussed for Plots R-1 and R-2, this increase seems to be due in large part to increased precipitation during the 1983 growing season but may also include some sampling error associated with different individuals estimating cover during the two years.

Planted grasses averaged 26.0 percent cover for all treatment combinations, or 40.4 percent of total mean cover (Tables 6-11 and 6-12). Invader grass species averaged 10.4 percent cover, accounting for 16.2 percent of total mean cover. In spite of increased cover of planted species in 1983 relative to 1982, the proportion of total cover attributable to planted grasses decreased slightly. Invader species, on the other hand, experienced a 2.5-fold increase in cover relative to 1982. Proportionally, invader grasses increased far more than other grasses, forbs or shrubs. The increase associated with invaders seems to be related to increased cover of cheatgrasss and/or crested wheatgrass (Appendix 6-1.5). In the case of cheatgrass, increased moisture throughout the growing season may have allowed this species to flourish whereas in normal years it becomes dry and withered by the time cover estimates are made. Among the planted grasses, wheatgrass species continued to dominate, with Indian ricegrass and smooth

Table 6-12. Comparison of Mean Cover (%) Among Years for All Treatment Combinations on Experimental Revegetation Plot R-3, Tract C-a.

| Growth Form | Year | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1977 | 1978 | 1979 | 1980 | 1981 | 1982[1/] | 1983[1/] |
| Grasses Planted | 5.6 | 14.0 | 28.8 | 24.7 | 22.7 | 17.4 | 26.0 |
| Grasses Invaded | 0.8 | 0.5 | 1.5 | 3.4 | 3.0 | 4.1 | 10.4 |
| Forbs Planted | 8.0 | 5.1 | 3.5 | 4.0 | 7.3 | 6.6 | 10.6 |
| Forbs Invaded | 1.2 | 0.6 | 0.9 | 0.4 | 0.3 | 0.8 | 0.4 |
| Shrubs Planted | 4.7 | 7.2 | 16.7 | 4.0 | 4.4 | 13.6 | 16.1 |
| Shrubs Invaded | 0.0 | 0.1 | 0.2 | 0.1 | 0.2 | 1.0 | 0.8 |
| TOTAL | 20.3 | 27.5 | 51.6 | 36.6 | 37.9 | 43.5 | 64.3 |

1/ Data are based on cover estimates from sample quadrats established in 1982.

brome (Bromus inermis) being encountered frequently but contributing much lower cover than the wheatgrasses.

A statistical comparison of 1983 cover data for all planted and invader grasses showed that there were no significant differences based on the treatment combinations tested (Table 6-13). However, when cover based on individual planted grass species was compared among treatments, one significant main effect difference was noted (Table 6-14). Cover of smooth brome on hay mulched areas was significantly higher than on hydromulched sites, but neither of these mulch treatments supported cover significantly different from the no-mulch treatment (Appendix 6-1.6). These differences were not significant during 1982 but there was some indication that cover of brome was related to mulch. Though not evident in the analyses of the 1983 data, the 1982 cover of wheatgrasses was shown to be related to seeding rate. It is unclear why differences might be significant one year and not the next. Whatever the cause might be, it is not likely to be directly related to mulch treatments but rather to competition from other plant species which may have been influenced by mulch and/or seeding regimes at some point in the past.

Comparison of grass cover among years (Table 6-15) indicated that significant differences exist for both planted and invader species. Duncan's Multiple Range Test results (Appendix 6-1.6) illustrate that cover of invader grasses was significantly higher in 1983 than during any previous sample period. The situation for planted grasses was a bit more complex, with cover for 1983 being no different in a statistical sense from cover recorded in 1979 or 1980. However, the increase in cover from 1982 to 1983 was shown to be significant. This increase seems to be related, in part, to increased precipitation but no comparative data from the surrounding "natural" plant communities are available to corroborate this supposition.

Table 6-13. Results of Three-way ANOVA's Comparing Arcsine Transformed Cover Estimates for Planted and Invaded Grass, Forb, and Shrub Species During 1983 on Experimental Revegetation Plot R-3, Tract C-a.[1/]

| Growth Form | Source of Variation | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Substrate | | Mulch | | Seeding | | Substrate x Mulch | | Substrate x Seeding | | Mulch x Seeding | | Substrate x Mulch x Seeding | |
| | F | PR>F[2/] | F | PR>F[2/] | F | PR>F[2/] | F | PR>F[2/] | F | PR>F[2/] | F | PR>F[2/] | F | PR>F[2/] |
| Grasses Planted | 0.01 | 0.9120 | 0.10 | 0.9086 | 0.06 | 0.9415 | 0.09 | 0.9122 | 0.04 | 0.9585 | 0.35 | 0.8432 | 0.20 | 0.9374 |
| Grasses Invaded | 1.88 | 0.1768 | 1.78 | 0.1795 | 0.94 | 0.3964 | 0.22 | 0.7999 | 0.80 | 0.4575 | 0.18 | 0.9457 | 0.45 | 0.7725 |
| Forbs Planted | 1.14 | 0.2932 | 1.57 | 0.2237 | 1.56 | 0.2243 | 0.79 | 0.4612 | 1.21 | 0.3099 | 1.23 | 0.3172 | 0.24 | 0.9156 |
| Forbs Invaded[3/] | 0.45 | 0.5172 | 1.53 | 0.2550 | 0.83 | 0.4605 | 0.04 | 0.9567 | 0.72 | 0.5071 | 0.40 | 0.5414 | | |
| Shrubs Planted | 1.76 | 0.1817 | 0.64 | 0.5291 | 0.09 | 0.9128 | 0.88 | 0.4169 | 0.94 | 0.3940 | 0.79 | 0.5332 | 0.88 | 0.4758 |
| Shrubs Invaded | 0.86 | 0.4527 | 0.44 | 0.6962 | 0.04 | 0.9617 | 0.11 | 0.7683 | 0.29 | 0.6427 | 0.02 | 0.8964 | 0.00 | 0.9926 |

* Significant at $\alpha = 0.05$

** Significant at $\alpha = 0.025$

1/ Duncan's Multiple Range Test results for significant main effects are presented in Appendix 6-1.6.

2/ Represents the significance probability ( $\alpha$ ) associated with F.

3/ Missing values result from insufficient data to produce ANOVA results

Table 6-14. Results of Three-way ANOVA's Comparing Arcsine Transformed Cover Estimates for Planted Species Encountered During 1983 on Experimental Revegetation Plot R-3, Tract C-a.[1/]

| Growth Form | Source of Variation: Substrate F | Substrate PR>F[2/] | Mulch F | Mulch PR>F[2/] | Seeding F | Seeding PR>F[2/] | Substrate x Mulch F | Substrate x Mulch PR>F[2/] | Substrate x Seeding F | Substrate x Seeding PR>F[2/] | Mulch x Seeding F | Mulch x Seeding PR>F[2/] | Substrate x Mulch x Seeding F | Substrate x Mulch x Seeding PR>F[2/] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grasses Planted | | | | | | | | | | | | | | |
| *Agropyron* species | 0.11 | 0.7420 | 0.09 | 0.9161 | 0.09 | 0.9161 | 1.22 | 0.3198 | 0.29 | 0.7522 | 0.66 | 0.6250 | 0.62 | 0.6564 |
| *Agropyron trichophorum* | 0.12 | 0.7316 | 0.03 | 0.9698 | 1.64 | 0.2213 | 0.88 | 0.4326 | 0.33 | 0.7264 | 0.82 | 0.5276 | 0.16 | 0.9569 |
| *Bromus inermis* | 0.36 | 0.5616 | 5.05* | 0.0256 | 2.59 | 0.1159 | 0.01 | 0.9930 | 0.93 | 0.4201 | 2.00 | 0.1590 | 0.25 | 0.9032 |
| *Oryzopsis hymenoides* | 0.32 | 0.5864 | 0.12 | 0.8915 | 0.33 | 0.7234 | 0.95 | 0.4178 | 1.45 | 0.2809 | 0.09 | 0.9843 | 0.38 | 0.6905 |
| *Stipa viridula* | 0.82 | 0.3913 | 0.23 | 0.8024 | 0.54 | 0.6045 | 0.13 | 0.8805 | 0.65 | 0.5487 | 1.11 | 0.3987 | 0.00 | 1.0000 |
| Forbs Planted | | | | | | | | | | | | | | |
| *Astragalus cicer* | 0.29 | 0.5962 | 3.48 | 0.0527 | 0.34 | 0.7172 | 0.45 | 0.6452 | 2.04 | 0.1593 | 0.93 | 0.4687 | 0.48 | 0.7490 |
| *Linum lewisii*[3/] | | | | | | | | | | | | | | |
| *Melilotus officinalis*[3/] | | | | | | | | | | | | | | |
| Shrubs Planted | | | | | | | | | | | | | | |
| *Atriplex canescens* | 2.54 | 0.1305 | 0.11 | 0.8957 | 0.24 | 0.7887 | 2.93 | 0.0825 | 5.30** | 0.0171 | 3.02* | 0.0491 | 0.12 | 0.8866 |
| *Chrysothamnus nauseosus*[3/] | 2.86 | 0.1415 | 3.68 | 0.0907 | 1.97 | 0.2201 | 0.36 | 0.7107 | 0.32 | 0.7381 | 1.27 | 0.3665 | | |
| *Certatoides lanata* | 0.04 | 0.8509 | 1.44 | 0.2675 | 1.67 | 0.2214 | 0.71 | 0.5053 | 5.03** | 0.0213 | 0.75 | 0.5757 | 1.46 | 0.2626 |
| *Purshia tridentata* | 0.68 | 0.4295 | 0.64 | 0.5517 | 1.56 | 0.2619 | 0.91 | 0.4360 | 0.40 | 0.6834 | 0.08 | 0.9872 | 1.74 | 0.2285 |

* Significant at $\alpha = 0.05$

** Significant at $\alpha = 0.025$

1/ Duncan's Multiple Range Test results for significant main effects are presented in Appendix 6-1.6.

2/ Represents the significance probability ($\alpha$) associated with F.

3/ Missing values result from insufficient data to produce ANOVA results

Table 6-15. Results of One-way ANOVA's Comparing Arcsine Transformed Cover Estimates for Grasses, Forbs, and Shrubs Between 1977, 1978, 1979, 1980, 1981, 1982 and 1983 for Experimental Revegetation Plot R-3, Tract C-a[1/]

| Growth Form | Source of Variation Year | |
|---|---|---|
| | F | PR>F[2/] |
| Grasses Planted | 28.31** | 0.0001 |
| Grasses Invaded | 18.63** | 0.0001 |
| Forbs Planted | 21.55** | 0.0001 |
| Forbs Invaded | 0.64 | 0.7008 |
| Shrubs Planted | 16.42** | 0.0001 |
| Shrubs Invaded | 1.44 | 0.2349 |

** Significant at $\alpha = 0.025$

1/ Duncan's Multiple Range Test results for significant main effects are presented in Appendix 6-1.6.

2/ Represents the significance probability ($\alpha$) associated with F.

Cover of planted forb species averaged 10.6 percent over all treatment combinations (Table 6-12), which accounts for approximately 16 percent of total mean cover. This represents the highest cover of planted forb species encountered since studies began in 1977. Differences between control and treatment portions of R-3 were slight, with cover averaging 11.0 percent for the control and 10.1 percent on the treatment site (Table 6-11). Highest cover varied between control and treatment portions of the plot but was encountered on hydromulched areas which had been seeded at either high or medium rates. Cover of invader forb species (0.4 percent) was the same on both control and treatment sides of the plot, and was one of only two categories to register a decrease in cover relative to 1982 data (Table 6-12). Cicer milkvetch was the primary contributor of cover for planted species (Appendix 6-1.5). Although yellow sweetcover and Lewis flax were encountered occasionally, their cover seemed to have decreased relative to previous years. A number of different invader forbs were encountered but no single species stood out as being dominant (Appendix 6-1.5).

Comparison of forb cover for 1983 showed no significant differences among any of the treatment combinations (Table 6-13). Similarly, when cover of individual planted forb species was tested no differences were evident (Table 6-14). However, the fact that enough data to complete the ANOVA was present only for Cicer milkvetch illustrates the reduced importance of other species, as noted above. Nevertheless, cover of planted forbs was shown to be significantly higher in 1983 than during other years since 1977 (Table 6-15, Appendix 6-1.6). These data illustrate the success of Cicer milkvetch for revegetation purposes but also show that richness of planted forb species may not be adequate in the long term. If competition from planted grasses, forbs and shrubs continues to be high, cover contributed by invader forbs cannot be expected to fill this void in forb cover. One possible solution to this potential problem would be to use additional forb species which are able to compete with grasses and/or to reduce the seeding rate for grasses.

Cover of planted shrub species averaged 16.1 percent on Plot R-3 during 1983, which accounted for 25.0 percent of the total mean cover (Table 6-12). Cover on the treatment portion of the plot was somewhat higher than on the control, 18.8 and 13.4 percent, respectively. There was considerable variability in cover among the various treatment combinations with the no mulch/high seeding combination underlain by processed shale exhibiting the highest overall cover (Table 6-11). Cover of invader shrub species averaged 0.8 percent over all treatments, which represented a slight decrease from 1982. The highest cover of invader species was found on the control area which received hydromulch and was seeded at the medium rate (Table 6-11, Figure 6-3). Fourwing saltbush and winterfat continue to be the dominant planted shrub species, with big sagebrush being an important invader. Although planted as containerized seedlings on Plot R-3, and listed as such on Table 6-11 and in Appendix 6-1.5, the majority of big sagebrush cover is believed to result from invasion. Combined cover of planted and invader shrubs during 1983 was only slightly lower than that recorded during 1979 in the original subplots sampled (Table 6-12).

A statistical comparison of 1983 cover for planted and invader shrub species grouped by growth form indicated no significant differences based on any of the treatment combinations tested (Table 6-13). However, when cover of individual planted species was compared among treatments, several significant first order interactions were noted (Table 6-14). Although two such differences were noted for fourwing saltbush, no main effect differences were significant. Similarly, the substrate x seeding interaction for winterfat was also significant but none of the main effects was significant at the five percent level. It is possible that in each of these instances the influences of the main effects are counteracting one another to some extent, thus masking main effect differences.

Significant differences also were evident among years for planted shrub species (Table 6-15). Duncan's Multiple Range Test results on this significant difference indicated that cover for 1983 was no different from that

recorded in 1979 and 1982. However these three years had cover significantly higher than all other years (Appendix 6-1.6). Shrub data for R-3 differ somewhat from those reported for Plots R-1 and R-2 during 1983 in that marked increases in cover over previous years were not noted. It is unclear why increased cover might have occurred on two plots while not also taking place on R-3. It should be noted that both R-1 and R-2 have had eight years of growth whereas R-3 has had only seven growing seasons.

b. Precipitation Data - Rainfall at Plot R-3 totalled 10.88 inches for the April-October 1983 period (Table 6-16). Unlike 1982 when the highest precipitation was recorded during September, May was the wettest month of the growing season during 1983. As noted for Plots R-1 and R-2, the 1983 rainfall was the highest recorded since R-3 was established in 1976. The low precipitation typically experienced during June-July was not evident in 1983. Increased average rainfall combined with more uniformity thoughout the growing season appears to have resulted in increased vegetative growth on R-3 as well as the other experimental revegetation plots.

c. Soil Moisture - Neutron probe soil moisture readings at three depths (approximately 25, 75 and 150 cm) within the reconstructed soil profile and/or processed shale at Plot R-3 were recorded monthly from May through October 1983. These data are summarized on Table 6-17 and are presented in their entirety in Appendix 6-1.5.

Corrected gauge readings (% of unit volume occupied by water) range from a high of 26.5 at the 25 cm depth in May to a low of 6.5 from a similar depth in September. However, the aforementioned moisture determinations are at different slope positions on R-3, as evident on Table 6-17. Because data are categorized by month, slope position and depth within the reconstructed profile, one can ascertain movement within the profile as well as downslope within the plot during the growing season.

Table 6-16. Rainfall (inches) Recorded at Experimental Revegetation Plots R-1, R-2 and R-3 during 1983, Tract C-a.

| Month | Plot R-1 | | Plot R-2 | | Plot R-3 | | Mean |
|---|---|---|---|---|---|---|---|
| | Upper | Lower | Upper | Lower | Upper | Lower | |
| April | 1.84 | 1.77 | 1.88 | 2.02 | 1.93 | ND | 1.89 |
| May | 2.32 | 2.31 | 2.29 | 2.46 | 2.33 | 2.61 | 2.39 |
| June | 1.49 | 1.38 | 1.34 | 1.62 | 1.42 | 1.40 | 1.44 |
| July | 1.28 | 1.25 | 1.23 | 1.23 | 1.30 | 1.20 | 1.25 |
| August | 1.43 | 1.27 | 1.28 | 1.38 | 1.27 | 1.20 | 1.30 |
| September | 1.10 | 1.07 | 0.97 | 1.06 | 0.98 | 1.04 | 1.04 |
| October | 1.62 | 1.47 | 1.60 | 1.64 | 1.65 | 1.49 | 1.58 |
| Gauge Total | 11.08 | 10.52 | 10.59 | 11.41 | 10.88 | 8.94[1/] | |
| Plot Mean | 10.80 | | 11.00 | | 10.88[2/] | | 10.89 |

1/ Data missing for the lower gauge during April.

2/ Plot mean based on 1.93 inches for both gauges during April.

TABLE 6-17. MEAN MONTHLY MOISTURE DETERMINATIONS (NEUTRON PROBE-CORRECTED READINGS, PERCENT VOLUME) FOR THREE SLOPE POSITIONS AND THREE DEPTHS WITHIN THE RECONSTRUCTED SOIL PROFILE ON EXPERIMENTAL REVEGETATION PLOT R-3, 1983

| SAMPLE MONTH | NO PROCESSED SHALE | | | | | | | | | PROCESSED SHALE | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LOWER SLOPE | | | MIDDLE SLOPE | | | HIGH SLOPE | | | LOWER SLOPE | | | MIDDLE SLOPE | | | HIGH SLOPE | | |
| | 25 CM | 75 CM | 150 CM | 25 CM | 75 CM | 150 CM | 25 CM | 75 CM | 150 CM | 25 CM | 75 CM | 150 CM | 25 CM | 75 CM | 150 CM | 25 CM | 75 CM | 150 CM |
| MAY | 25.5 | 21.3 | 10.2 | 24.2 | 21.2 | 14.6 | 26.2 | 21.3 | 16.6 | 26.5 | 20.7 | 9.6 | 25.6 | 22.3 | 17.8 | 25.6 | 22.8 | 17.8 |
| JUNE | 20.4 | 21.2 | 17.3 | 22.1 | 21.6 | 17.7 | 22.3 | 21.8 | 19.8 | 19.8 | 20.8 | 13.6 | 20.6 | 20.9 | 21.3 | 22.0 | 22.8 | 22.0 |
| JULY | 12.6 | 18.7 | 16.1 | 14.6 | 18.5 | 16.5 | 16.5 | 17.7 | 17.2 | 11.0 | 16.0 | 14.8 | 12.4 | 16.4 | 18.9 | 14.6 | 17.7 | 20.1 |
| AUGUST | 8.2 | 15.6 | 14.3 | 9.0 | 15.0 | 14.8 | 10.1 | 13.6 | 14.4 | 7.5 | 11.6 | 13.1 | 7.5 | 11.8 | 15.2 | 9.3 | 13.0 | 16.6 |
| SEPTEMBER | 7.4 | 11.6 | 12.1 | 7.6 | 10.7 | 13.0 | 7.8 | 9.7 | 11.3 | 7.2 | 8.5 | 10.1 | 6.5 | 7.8 | 11.6 | 7.1 | 8.0 | 12.7 |
| OCTOBER | 10.8 | 11.6 | 11.5 | 10.6 | 10.8 | 12.8 | 11.7 | 10.0 | 11.4 | 10.2 | 8.1 | 10.3 | 9.9 | 7.9 | 11.8 | 9.8 | 7.9 | 12.3 |
| SUMMARY STATISTICS: | | | | | | | | | | | | | | | | | | |
| MEAN: | 14.2 | 16.7 | 13.6 | 14.7 | 16.3 | 14.9 | 15.8 | 15.7 | 15.1 | 13.7 | 14.3 | 11.9 | 13.8 | 14.5 | 16.1 | 14.7 | 15.4 | 16.9 |
| STANDARD DEVIATION: | 1.27 | 1.34 | 1.23 | 1.12 | 1.73 | 2.17 | 1.23 | 2.08 | 3.10 | 1.52 | 1.28 | 1.73 | 1.03 | 1.10 | 3.22 | 1.23 | 1.42 | 3.12 |

Moisture in the surface component of the profile (approximately 25 cm) decreased from May through September and then increased again in October. Moisture within the middle of the reconstructed profile (approximately 75 cm) also decreased but did not reach as low a level as that of surface soils nor did moisture increase in October. At the deepest portion of the profile (approximately 150 cm) moisture increased during June and July relative to May, and then began to decrease, reaching levels lower than those recorded in May. Based on these data it seems reasonable to conclude that the quantity of moisture during the spring was sufficient to result in movement throughout the reconstructed soil profile.

The general depletion of moisture from the profile during the growing season was expected. Because downward movement of moisture beyond the reconstructed profile and processed shale was restricted by a plastic liner, and because no moisture had been collected from the leachate collection system at R-3, the reduced moisture readings at the bottom of the profile toward the end of the growing season probably resulted from capillary rise and/or transpiration from plants. However, this decrease in moisture at the depth occurred in the processed shale as well as the control portion of the plot. It has been determined from excavations during 1982 that few roots reach as far as the processed shale; therefore, the majority of the reduction in moisture within the shale probably does not result from use by plants but rather by capillary action.

Statistical comparisons of moisture data revealed significant differences between substrates for the second half of the growing season, among slope positions for the first three months and among depths for all six months (Table 6-18). Results of Duncan's Multiple Range Tests (Appendix 6-1.6) illustrate that during August, September and October moisture on the control portion (no shale) of the plot was significantly higher than the portion underlain with processed shale. These differences may be related to moisture at depth within the reconstructed profile. During the same three-month period, moisture at the 150 cm depth was significantly higher

Table 6-18. Results of Analysis of Variance Comparing 1983 Neutron Probe Moisture Determinations Among Substrates, Slope Positions and Sample Depths with the Reconstructed Soil Profile on Plot R-3, Tract C-a.

| Sample Month | Source of Variation | | | | | |
|---|---|---|---|---|---|---|
| | Substrate | | Slope Position | | Depth | |
| | F | PR>F 2/ | F | PR>F 2/ | F | PR>F 2/ |
| May | 2.12 | 0.1481 | 7.68** | 0.0008 | 123.57** | 0.0001 |
| June | 0.00 | 0.9441 | 13.11** | 0.0001 | 15.24** | 0.0001 |
| July | 3.05 | 0.835 | 11.66** | 0.0001 | 37.76** | 0.0001 |
| August | 7.67** | 0.0067 | 2.90 | 0.0596 | 95.89** | 0.0001 |
| September | 14.27** | 0.0003 | 0.09 | 0.9140 | 60.72** | 0.0001 |
| October | 20.33** | 0.0001 | 0.11 | 0.8956 | 16.30** | 0.0001 |

* Significant at $\alpha = 0.05$

** Significant at $\alpha = 0.025$

1/ Duncan's Multiple Range Test Results for significant main effect differences are presented in Appendix 6-1.6.

2/ Represents the significance probability ( $\alpha$ ) associated with F.

than at the other two sample depths. This combination of substrate and depth differences seems to indicate that moisture movement into the processed shale occurrs at a slower rate than within the overburden material at a similar depth in the reconstructed soil profile.

Although moisture (% volume) was significantly higher at the surface than at depth during May, by June the top 75 cm of the profile was the same and by July moisture had moved to the lower half of the profile. At this point in the growing season moisture at the surface (25 cm) was significantly lower than the remainder of the profile, a situation which continued until October when fall precipitation and lower evapotranspiration may have resulted in a slight recharge of surface moisture. Nevertheless, moisture at 150 cm was still higher than that at 25 cm at the end of the growing season (Appendix 6-1.6).

Variations in moisture among slope positions during the first half of the growing season are not easily explained. One might expect that moisture would move downgradient during the growing season but this did not seem to be the case. The high and medium slope positions were similar in moisture content during the May-June interval. All three slope positions were distinctly different during July, with the highest readings at the top of the plot. Removal of moisture from the reconstructed profile via evapotranspiration during the growing season probably kept moisture levels below field capacity, thus limiting movement downgradient. If precipitation on Tract C-a were to increase markedly, one might expect to see downgradient movements but this is unlikely given the present climatic regime. In fact, if precipitation levels return to those recorded during 1977-1981 when very low rainfall was received during June-July, moisture status within the reconstructed profile would likely change dramatically. Reduced moisture at depth and a more rapid depletion of moisture throughout the profile during the growing season would be expected.

## 6.2 MULE DEER HABITAT MODIFICATION STUDY

### 1. Objectives

During RBOSC's commercial operation, disturbances of the land will result in the loss of habitat and forage for wildlife, primarily mule deer. One means of mitigating these losses is to increase the mule deer carrying capacity of undisturbed areas to maintain the overall carrying capacity at, or near, predevelopment levels. RBOSC initiated an experiment in 1980 to determine the feasibility of producing such increases in carrying capacity using the habitat modification techniques described below.

### 2. Methods

The critical factor which currently limits mule deer populations in the Piceance Creek Basin is the availability of suitable food during periods of heavy snow cover. Thus, a program designed to increase the carrying capacity of local habitats for mule deer should be aimed at increasing suitable forage as well as providing access for mule deer to these modified areas during periods of heavy snow cover. Habitat modification in large, continuous blocks increases wildlife forage, but such large areas commonly fill with snow during periods of heavy snowfall making the area inaccessible to deer. The RBOSC habitat modification program is designed to avoid this problem by modifying vegetation in strips, leaving the vegetation between strips undisturbed. The undisturbed strips provide cover and access routes to the modified areas. The RBOSC study design is discussed in further detail in MDP Monitoring Report Nine (RBOSC 1982). The location of the study site is illustrated in Figure 6-4.

### 3. Results and Discussion

The mule deer habitat modification study site testing brush removal via rotochopping was not sampled during the 1983 field season. Subsequent sampling will be accomplished as per the Scope of Work.

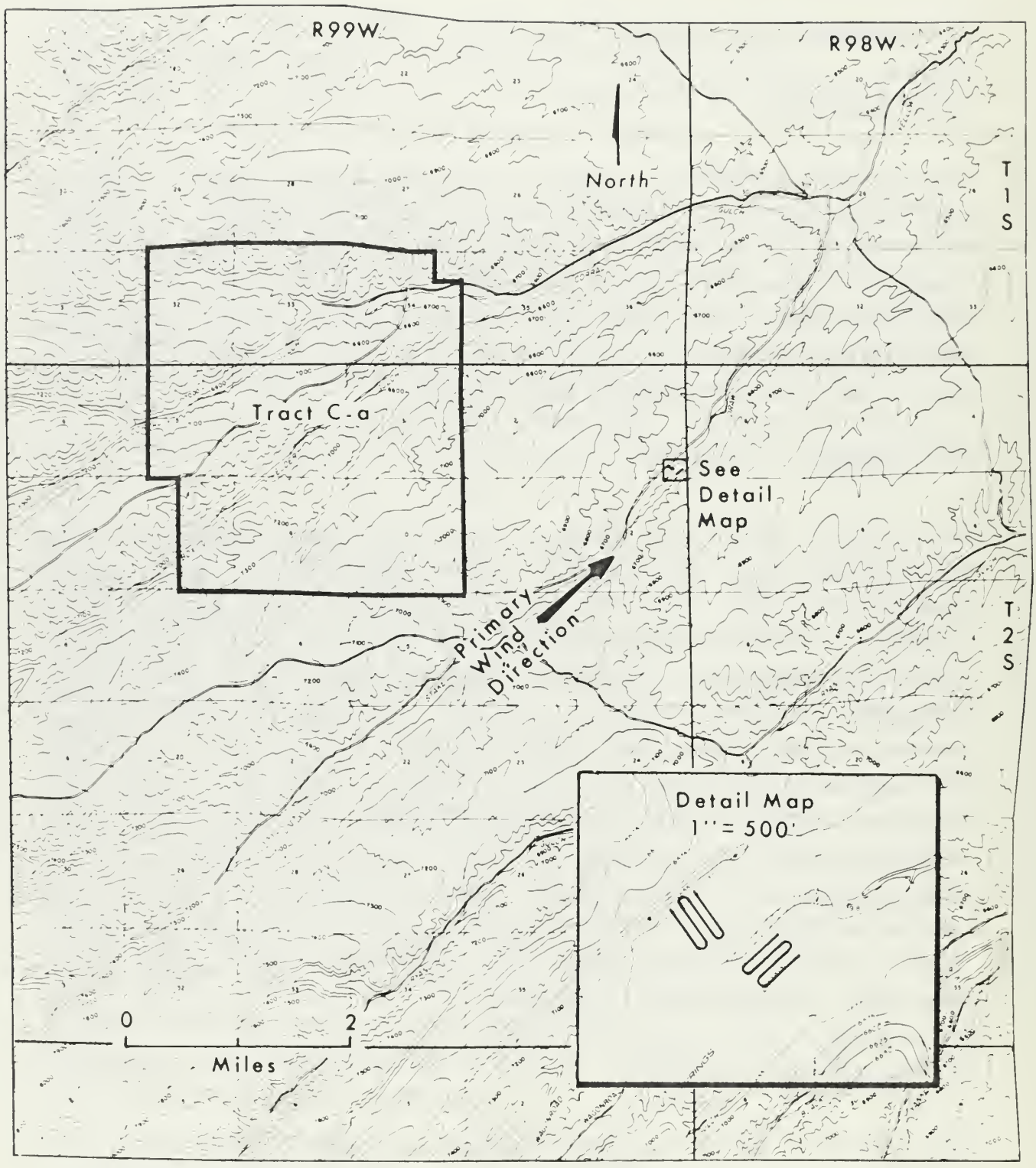



Figure 6-4. Location of Mule Deer Habitat Modification Study

## 6.3 SHRUB GROWTH ENHANCEMENT ON A SIMULATED MINE SITE AND/OR DISPOSAL PILE BENCH

### 1. Objectives and Rationale

Reclamation of areas disturbed by Tract C-a activities will be accomplished according to a state and federally approved reclamation plan. Reclamation techniques implemented by RBOSC are expected to result in adequate habitat for livestock and wildlife. Additional steps which reduce the amount of time necessary to establish such habitat are desirable. Shrub growth enhancement through water harvesting is an example of one such technique. The objective of this study is to test water harvesting techniques as a means of habitat establishment and enhancement.

In the semiarid environment of the Piceance Basin, increased shrub growth may be achieved by augmenting soil moisture via water harvesting techniques. Water harvesting is a technique designed to conserve and more efficiently utilize normal runoff by concentrating runoff from a large area into a smaller area where it is available for use by plants.

To reduce the potential for soil erosion, benches may be required on long slopes resulting from Tract C-a mining and/or disposal activities. To test the influence of increased moisture on shrub growth for wildlife cover, water harvesting techniques are being incorporated into a simulated mine site/disposal pile bench on a southeast-facing slope within Box Elder Gulch on Tract C-a (see Figure 6-7).

### 2. Methods

The design of the simulated mine site/disposal pile bench is presented in Figures 6-5 and 6-6. Water from accumulated snowpack, runoff from snow melt, and rainfall should concentrate along the two rows of shrubs on the 6:1 (horizontal:vertical) bench slope (Rows B and C). Increased moisture should also be available to the shrubs in the water bar below the bench

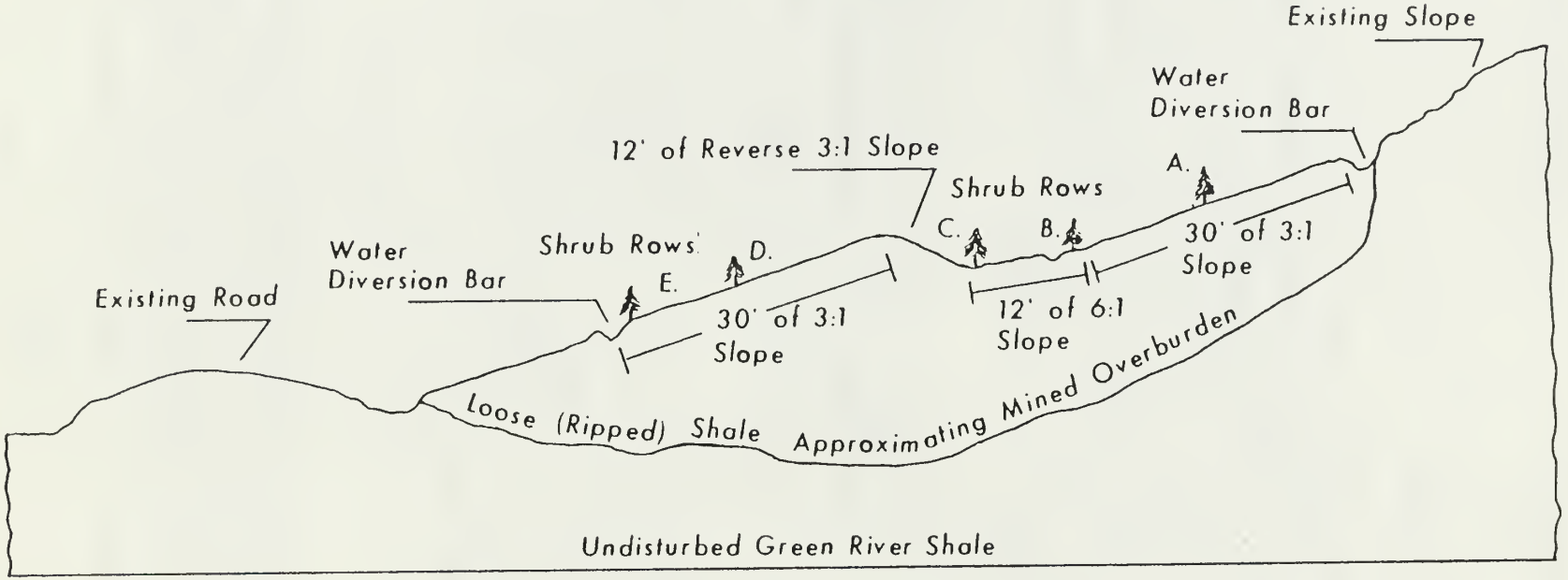



Figure 6-5. Cross Section of Simulated Mine Bench for Testing of Shrub Growth through Water Harvesting.

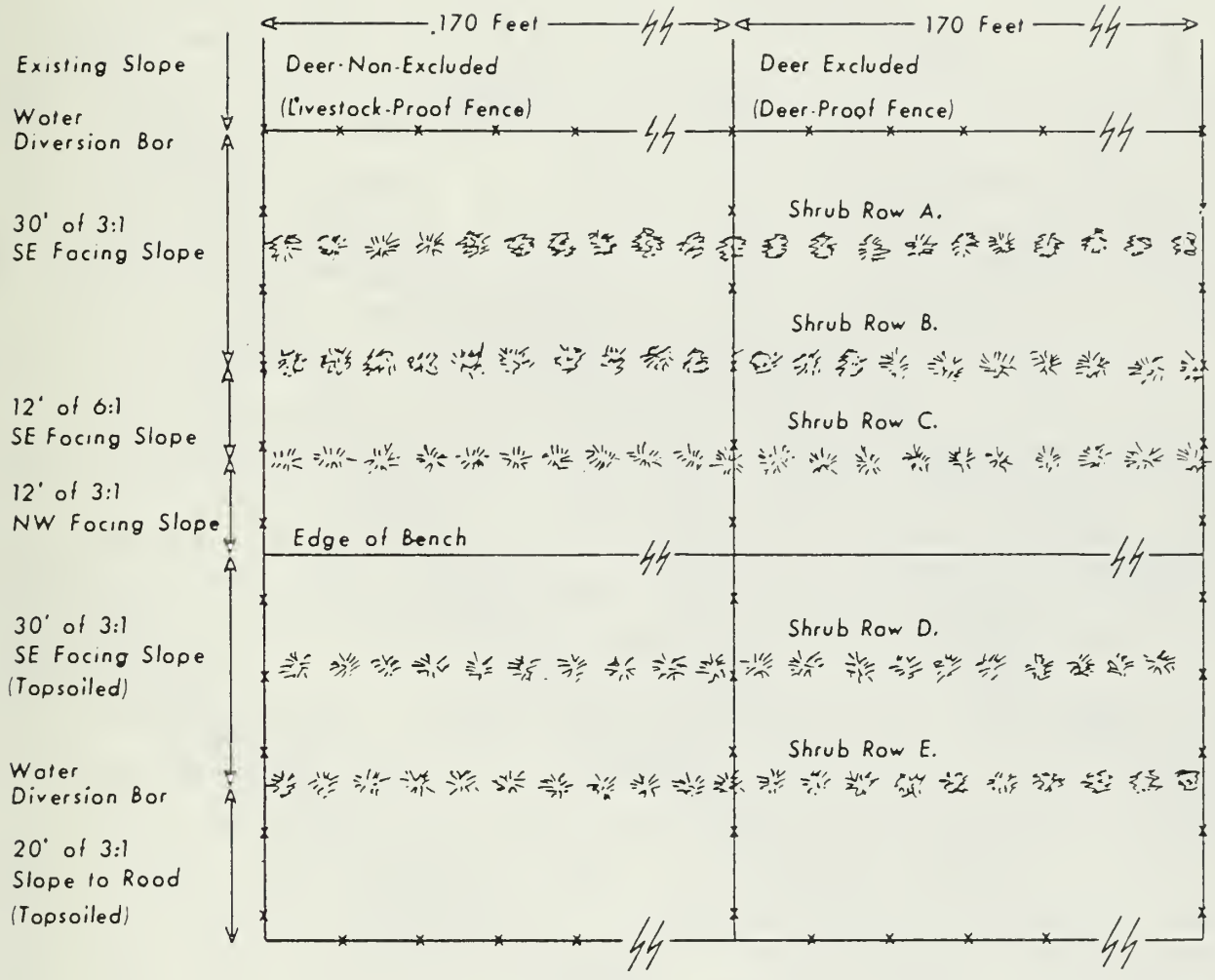
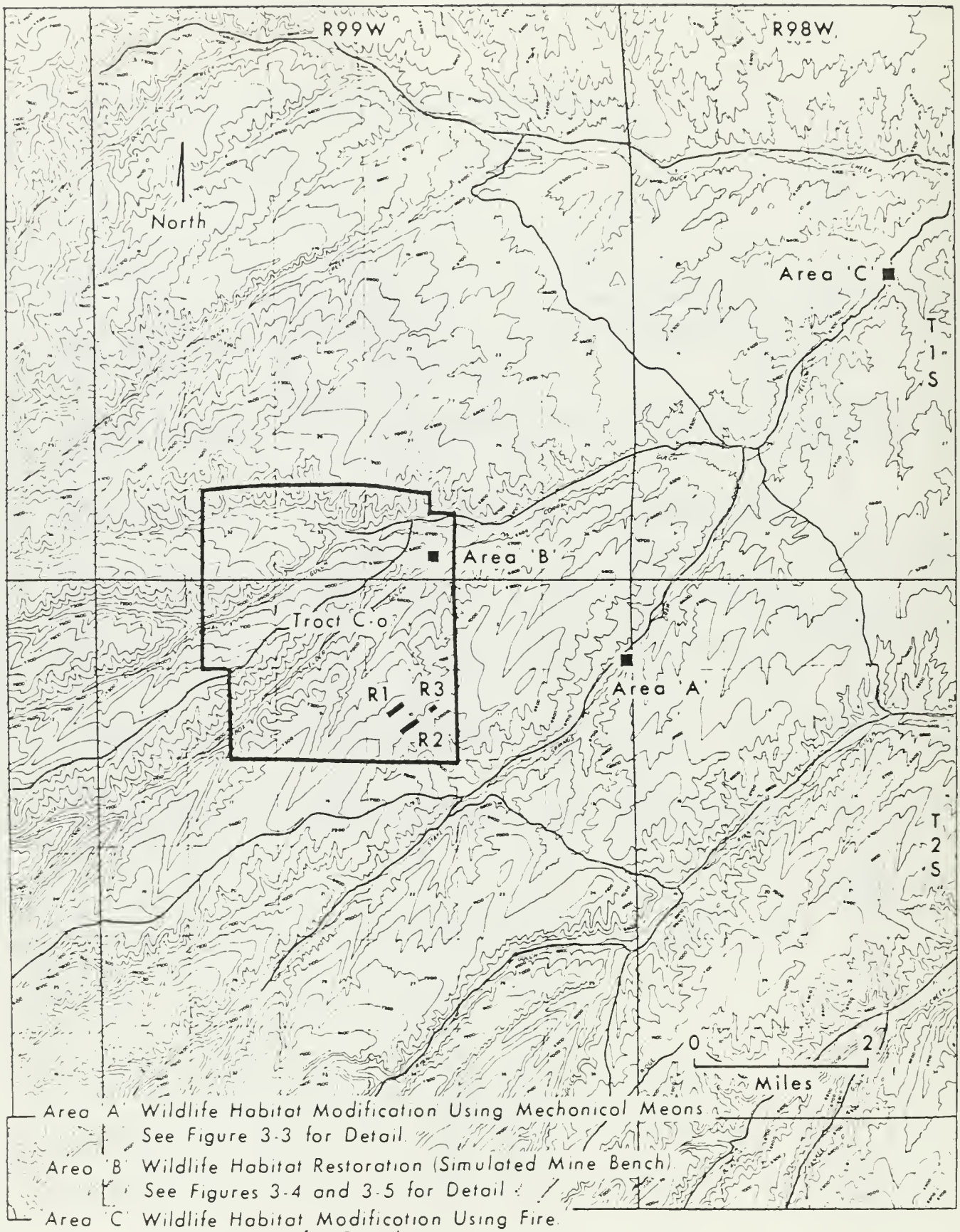



Figure 6-6. Aerial View of Simulated Mine Bench for Testing Enhancement of Shrub Growth through Water Harvesting




Area 'A' Wildlife Habitat Modification Using Mechonicol Meons
See Figure 3-3 for Detail.

Area 'B' Wildlife Habitat Restoration (Simulated Mine Bench)
See Figures 3-4 and 3-5 for Detail.

Area 'C' Wildlife Habitat Modificotion Using Fire.
See Figure 3-6 for Detail.

R1, R2, R3 Experimental Revegetation Sites.

Figure 6-7. Terrestrial Ecology Special Study Sites

(Row E). The rows of shrubs on the 3:1 slope between the bench and the lower water bar (Row D), and the row of shrubs above the bench (Row A) serve as controls, where shrub growth without increased moisture will be monitored.

In order to establish wildlife cover rapidly, five of the seven shrub species planted in the test area are not normally used as food by deer: New Mexico foresteria (Foresteria neomexicana), Apache plume (Fallugia paradoxa), New Mexico black locust (Robinea neomexicana), oldman wormwood (Artemisia abrotanum), and Skunkbrush sumac (Rhus trilobata). Serviceberry (Amelanchier alnifolia) and fourwing saltbush (Atriplex canescens), choice deer food, were included to test the effect of deer browsing pressure on shrub growth. One-half of the test is fenced to exclude deer and cattle, and the other half is fenced to exclude cattle but allow deer entry. All shrub species were planted as tublings in June of 1982. Shrubs were watered at the time of planting and irrigated as necessary during the first summer to ensure establishment; if necessary, one-half of all shrub rows on the bench and in the waterbar will be irrigated for the following two summers, to test the effect of irrigation on shrub growth. All areas between shrub rows were planted with the RBOSC seed mixture illustrated on Table 6-19.

The ultimate goal of harvesting water to enhance shrub growth on the simulated mine bench test is to provide vegetation cover for deer within four years. In the Piceance Basin, this cover is necessary for thermal protection and predator avoidance. This cover is normally provided by pinyon-juniper forests, tall sagebrush in bottomlands and other areas of tall, dense vegetation. At the onset of this test, it was decided that a shrub height of four feet (ca 120 cm.) would be the lower limit of adequate cover for mule deer. A similar sized diameter was also considered important for each shrub. Because the seven species of shrubs used in the test have different growth rates and physiognomy, it was necessary to compare shrub

Table 6-19. Seed Mixture Used in Final Reclamation by RBOSC

| Plant Species | Seeding Rate (Kg/Ha) |
|---|---|
| Pubescent Wheatgrass (Agropyron trichophorum) | 3.0 |
| Western Wheatgrass (Agropyron smithii) | 4.2 |
| Streambank Wheatgrass (Agropyron riparium) | 2.4 |
| Indian Ricegrass (Oryzopisis hymenoides) | 1.8 |
| Green Needlegrass (Stipa viridula) | 1.8 |
| Smooth Brome (Bromus inermis) | 1.8 |
| Cicer Milkvetch (Astragalus cicer) | 1.8 |
| Yellow Sweetclover (Melilotus officinalis) | 0.9 |
| Lewis Flax (Linum lewisii) | 1.2 |
| Winterfat (Ceratoides lanata) | 1.2 |
| Fourwing Saltbush (Atriplex canescens) | 1.2 |
| Bitterbrush (Purshia tridentata) | 1.2 |
| TOTAL | 22.50 |

growth performance by a common index. A plant height - plant diameter (PH-PD) index was developed, as derived by the following formula:

$$PH\text{-}PD = \frac{\frac{\text{Shrub Height (cm)}}{120\text{ cm}} + \frac{\text{Shrub Diameter (cm)}}{120\text{ cm}}}{2}$$

This index provides information on how well shrubs in the various treatments on the simulated mine bench achieve the lower limit of adequate cover (120 cm). This lower limit will be reached when the PH-PD index is equal to one.

Shrub measurements (plant height and diameter) of each individual are made on a monthly basis during the growing season. These data are then used in determining the PH-PD index. Plant mortality was also noted each month.

In order to test the effectiveness of the water harvesting technique, moisture content is measured monthly during the growing season within the soil profiles on control and treatment portions of the simulated bench. Permanently placed soil access tubes allow for repeated soil moisture determinations at the same locations using a Troxler Depth Moisture Gauge.

Success of revegetation efforts between shrub rows (those areas seeded with species listed on Table 6-19) is monitored along permanently established transects within treatment areas. Transects are placed during the first growing season after planting and are marked at both ends with stakes. Aluminum marking tags identifying the transect number, as well as the beginning and/or end of the transect, are attached to these stakes. Transects are 40 m in length and are oriented perpendicular to the existing slope whenever possible.

Cover of grasses, forbs, and shrubs is estimated annually within sampling frames (1 $m^2$) placed at five-meter intervals along the transects. A meter tape stretched between the stakes at either end of the transect allows exact placement of these frames. Sampling frames are subdivided into 5 percent segments and cover of individual species is estimated to the nearest one

percent. All data are recorded on field data forms, which are formatted for direct computer entry.

3. Results and Discussion

a. Shrub Survival - Percent survival of all shrub species by treatment is presented in Table 6-20. From this table it can be seen that different shrub species and different treatments exhibited varying survival rates. It should be noted that two individuals of the shrub species - serviceberry, oldman wormwood, Apache plume, and skunkbrush sumac were planted at each designated location in Rows B and C to insure adequate survival for testing purposes. If both individuals are alive at the beginning of the 1984 growing season, the weaker one will be removed. It should also be noted that these species were of greenhouse stock, eight months old; that individuals of the fourwing saltbush were of uneven age, from eight to eighteen months; and, that the New Mexico black locust and New Mexico foresteria were 18 months old at planting.

The lowest survival was found in serviceberry and, consequently, this species is probably not suited for reclaiming a southeast-facing slope at 6800 feet elevation. Oldman wormwood and skunkbrush sumac both exhibited good survival but not as high as some other species. New Mexico black locust was the only species with 100 percent survival.

Most species with the exception of serviceberry and fourwing saltbush had similar survival rates in both the deer excluded and the deer not excluded fencing treatments. These species are the most palatable to deer of those in the test and exhibited severely reduced survival where deer had access for browsing.

Row C had the highest overall survival among the water harvesting and topsoil treatments. This row did not receive the highest overall water availability based on neutron probe measurements, therefore moisture may not

Table 6-20. Percent Survival of all Shrub Species by Treatment on the Simulated Mine Bench Test in September 1983.

| | Deer Excluded Row | | | | | | Deer Not Excluded Row | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | Ave. | A | B | C | D | E | Ave. |
| Amelanchier alnifolia | 33 | 67 | 83 | 33 | 33 | 50 | 0 | 57 | 83 | 0 | 0 | 28 |
| Artemisia abrotanum | 100 | 80 | 100 | 67 | 67 | 83 | 100 | 83 | 100 | 50 | 83 | 83 |
| Atriplex canescens | -1/ | 100 | 100 | 100 | 67 | 92 | - | 17 | 17 | 71 | 33 | 35 |
| Fallugia paradoxa | - | 100 | 100 | - | - | 100 | - | 60 | 83 | - | - | 71 |
| Foresteria neomexicana | - | 100 | 100 | 67 | 83 | 87 | - | 100 | 100 | 100 | 100 | 100 |
| Rhus trilobata | 83 | 100 | 100 | 100 | 50 | 87 | 67 | 100 | 100 | 67 | 33 | 73 |
| Robinea neomexicana | - | 100 | 100 | - | - | 100 | - | 100 | 100 | - | - | 100 |
| Average | 72 | 92 | 98 | 73 | 60 | 86 | 56 | 70 | 83 | 58 | 50 | 70 |

1/ - Indicates no shrubs of a particular species were planted in that treatment.

have contributed greatly to high shrub survival. The snow pack during the winter of 1982-83 was deepest along this row and generally covered all shrubs completely which could have enhanced survival by reducing the potential for wind desiccation and/or freezing.

The lowest shrub survival was found in Row E, the waterbar/topsoil treatment. Two factors may have contributed to this low survival: topsoil settling in the waterbar and frost heaving, the combination of which seemed to have caused the root mass of many shrubs to be exposed resulting in dessication. The topsoil was placed on the bench test about two months prior to planting which may account for the settling observed during the first winter. In lieu of waiting a winter season for soils to stabilize, techniques resulting in enhanced protection from desiccation at the time of planting would be recommended.

The fence treatment that excluded deer had a higher overall shrub survival than the fence treatment that allowed deer access to browse. Even shrub species not usually chosen as food by deer were slightly browsed as deer "tested" for palatability. When a shrub is small, this limited browsing can have a significant effect on survival. Differences in shrub survival between the fencing treatments should be smaller in succeeding years.

b. Shrub Growth - Means of the PH-PD index for each shrub species by row and fence treatments for September 1983 are presented in Table 6-21 and individual measurements for September 1983 are presented in Appendix 6-3.1. Additional monthly data are included in RBOSC's data base should within season growth rates need to be determined. Overall shrub growth of most species was the same in both fencing tests. Deer browsing apparently had no significant effect on the average growth attained during the growing season. However, the index for saltbush, a palatable species, was lower where exposed to browsing.

Table 6-21. Means of the Plant Height-Plant Diameter (PH-PD) Index for Each Shrub Species by Treatment on the Simulated Mine Bench Test in September 1983.

| | Deer Excluded Row | | | | | | Deer Not Excluded Row | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | Ave. | A | B | C | D | E | Ave. |
| Amelanchier alnifolia | .10 | .10 | .09 | .07 | .11 | .09 | 0 | .17 | .12 | 0 | 0 | .15 |
| Artemisia abrotanum | .29 | .23 | .25 | .22 | .35 | .27 | .31 | .20 | .27 | .20 | .26 | .25 |
| Atriplex canescens | -1/ | .54 | .67 | .70* | .64 | .64 | - | .72 | .41* | .56 | .50 | .55 |
| Fallugia paradoxa | - | .27 | .27 | - | - | .27 | - | .24 | .32 | - | - | .28 |
| Foresteria neomexicana | - | .32 | .38 | .27 | .41 | .35 | - | .38* | .33* | .23 | .17 | .28 |
| Rhus trilobata | .23 | .24 | .26 | .14 | .25 | .22 | .22 | .20 | .30 | .09* | .26 | .21 |
| Robinea neomexicana | - | .51 | .46 | - | - | .49 | - | .50 | .62 | - | - | .56 |
| Average | | | | | | .33 | | | | | | .33 |

1/ - Indicates no shrubs of a particular species were planted in that treatment.

* - Significantly different measurement at the P>0.05 level of probability within a species.

The effects of topsoil and potentially increased moisture on shrub growth were not evident within the shrub species. None of the treatments resulted in significant trends that might indicate an increase or decrease in overall growth of any of the shrub species tested.

Nevertheless, some differences in growth were evident among species. Saltbush and New Mexico black locust, two of the species that were older than most others at the time of planting, had the highest PH-PD index of all shrubs. The lowest index was exhibited by serviceberry followed by skunkbrush sumac and oldman wormwood, the youngest shrubs at planting. These data support the supposition that serviceberry is probably not suited for reclamation on such a site. However, shrub age differences should be less apparent with time, and final conclusions should not be made until data from several growing seasons are available.

c. Soil Moisture - Neutron probe moisture determinations data are summarized on Table 6-22 and are presented in their entirety in Appendix 6-3.2. Moisture in surface soils (to a depth of approximately 25 cm) appeared to decrease from May through September and then increase slightly in October. This pattern was evident in all five rows. A similar pattern was noted on Experimental Revegetation Plot R-3 during the 1983 growing season. The lower moisture during mid-summer may be related to greater evapotranspiration associated with high temperatures as compared to spring or fall. Lower temperatures and slight increases in rainfall during October may account for the increased moisture at the end of the growing season. Moisture determinations at both 75 and 150 cm depths from all five rows also exhibited slight decreases throughout the growing season. However, these decreases were not as pronounced as those experienced at the 25 cm depth nor were increases during October as evident.

In order to determine if variations in moisture among rows and/or among locations within rows were significantly different, data were compared using a two-way Analysis of Variance. The results of these comparisons, as

TABLE 6-22. MEAN MONTHLY MOISTURE DETERMINATIONS (NEUTRON PROBE-DIRECT READINGS, PERCENT VOLUME) FOR THREE DEPTHS SAMPLED IN FIVE ROWS ON THE BENCH DURING 1983

| SAMPLE MONTH | ROW A | | | ROW B | | | ROW C | | | ROW D | | | ROW E | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 25CM | 75CM | 150CM | 25CM | 75CM | 150CM | 25CM | 75CM | 150CM | 25CM | 75CM | 150CM | 25CM | 75CM | 150CM |
| MAY | 31.2 | 32.2 | 31.8 | 31.5 | 29.5 | 32.9 | 30.5 | 29.6 | 30.2 | 32.8 | 23.7 | 26.5 | 34.6 | 33.6 | 33.0 |
| JUNE | 29.5 | 31.6 | 31.5 | 30.0 | 28.8 | 30.4 | 29.2 | 28.8 | 29.3 | 29.6 | 24.6 | 26.3 | 32.2 | 32.9 | 32.2 |
| JULY | 28.1 | 32.1 | 31.7 | 27.1 | 27.1 | 29.0 | 28.3 | 28.8 | 29.9 | 23.6 | 23.3 | 26.3 | 29.4 | 32.5 | 32.5 |
| AUGUST | 25.3 | 31.4 | 31.8 | 28.8 | 29.1 | 30.2 | 27.9 | 29.5 | 29.8 | 21.7 | 22.0 | 26.0 | 27.0 | 32.3 | 32.2 |
| SEPTEMBER | 21.2 | 28.3 | 30.7 | 25.9 | 27.8 | 29.8 | 25.6 | 27.9 | 30.0 | 19.8 | 20.4 | 25.3 | 25.0 | 30.8 | 31.5 |
| OCTOBER | 24.4 | 28.2 | 31.2 | 28.9 | 28.3 | 29.6 | 27.7 | 29.0 | 29.4 | 21.3 | 19.6 | 25.1 | 26.9 | 31.5 | 31.9 |
| SUMMARY STATISTICS: | | | | | | | | | | | | | | | |
| MEAN: | 26.6 | 30.6 | 31.5 | 28.7 | 28.4 | 30.3 | 28.2 | 29.0 | 29.8 | 24.8 | 22.3 | 25.9 | 29.2 | 32.3 | 32.2 |
| STANDARD DEVIATION: | 3.4 | 2.5 | 3.4 | 4.3 | 3.1 | 4.2 | 2.4 | 2.0 | 5.0 | 2.8 | 3.7 | 9.0 | 3.1 | 2.0 | 4.8 |

summarized on Table 6-23, indicate that significant differences exist among rows as well as among access tube locations throughout the study site.

Duncan's Multiple Range Tests illustrate that although the moisture in surface soils (to a depth of 25 cm) was highest in Row E, there was no significant difference between rows B, C, or E (Appendix 6-3.2). In this instance the highest moisture corresponds to the row with the lowest percent survival of all species. Furthermore, high growth indices do not correspond with areas of highest moisture, as indicated by neutron probe readings. It is unclear why growth is not directly related to moisture. However, it is possible that erroneous readings are being obtained, perhaps due to the shale substrate present on the bench site. Another factor may be related to plant available moisture rather than total moisture as measured by neutron probe readings. This is not to imply that augmentation of moisture for increased plant growth is not a worthwhile endeaver but rather that the methods used in this study have not confirmed that moisture has been effectively "harvested".

The relationship of moisture among rows changes somewhat as depth within soil/overburden on the simulated bench increases. But, in all instances, the moisture levels appear to be highest in Row E and lowest in Row D regardless of depth (Appendix 6-3.2). At the 75 cm depth recorded values in Row E were significantly higher than in all other rows. Data based on the placement of sample tubes (positions 1-8 as ordered from east to west) seem to indicate that some channeling of moisture may occur at depths within the overburden on the bench site. Positions 2 and 3 had significantly lower moisture at the 150 cm depth than any of the other tube positions (Appendix 6-3.2). A similar, though less distinct, trend was also noted at the 75 cm depth. For the most part, moisture within surface soils did not appear to be influenced by position along a row, as determined by the location of sample tubes.

Table 6-23. Summary of ANOVA Results Comparing Moisture Determinations at Three Depths (25, 75, 150 cm) by Row and Access Tube Location on the Simulated Bench Study Site, Tract C-a[1/].

| Sample Depth (cm) | Row | | Access Tube Location | |
|---|---|---|---|---|
| | F | PR>F[2/] | F | PR>F[2/] |
| 25 | 7.63** | 0.0001 | 1.76 | 0.0962 |
| 75 | 88.98** | 0.0001 | 4.91** | 0.0001 |
| 150 | 17.51** | 0.0001 | 27.79** | 0.0001 |

* Significant at $\alpha = 0.05$

** Significant at $\alpha = 0.025$

1/ Duncan's Multiple Range Tests for significant main effects are presented in Appendix 6-3.2

2/ Represents the significance probability ($\alpha$) associated with F

As roots from the shrubs extend to greater depths within the soils/ overburden on the bench, it is possible that the potential channeling could influence plant growth. However, during the first several years of growth, roots are undoubtedly concentrated nearer the surface where these variations are not evident.

## 6.4 STUDY TO ALTER NATURAL SUCCESSION AFTER FIRE FOR ENHANCED DEER-LIVESTOCK FORAGE

### 1. Objectives and Rationale

During RBOSC's commercial operation, disturbance of land will result in the loss of forage for wildlife, including mule deer, and for livestock. One means of mitigating these losses is to increase the amount of available forage in undisturbed areas thereby maintaining carrying capacity in the area at, or near, predevelopment levels. A factor important to wintering mule deer is the availability of quality green forage early in the spring. Spring "green-up" time is a period during which deer begin to recoup body nutrients lost throughout the winter. In the spring, deer congregate in large numbers in hay fields and meadows where a high density of newly emerged plant sprouts occurs. This critical forage area for deer is also an important summer grazing area for livestock.

Many creek bottoms in the vicinity of Tract C-a are covered with rank sagebrush, rabbitbrush and greasewood, and serve as wintering areas for wildlife. If a very small percentage of these bottoms were converted into areas providing quality forage for spring "green-up" and summer grazing, the carrying capacity of the region might be increased.

The use of fire to "set back" plant succession and to remove undesirable plant species is quite common (Wright et al, 1979). However, succession after several natural fires in Yellow Creek and Duck Creek northeast of Tract C-a has not resulted in vegetation more suitable for wildlife in these areas. RBOSC initiated an experiment in 1982 to determine the feasibility of producing such increases using the habitat modification techniques described below.

## 2. Methods

When a natural fire occurred in September 1981 approximately 4 miles down Yellow Creek from the confluence with Corral Gulch (Area 'C' in Figure 6-7), the opportunity was taken to set up a program to study methods which might improve the suitability of vegetation. Techniques used in this study included seeding more desirable plant species, and excluding grazing by livestock and deer.

In late March 1982, the plant species were seeded in the Yellow Creek Burn Area as shown on Table 6-24 and Figure 6-8. Two seeding rates were used (21 and 43 kg/ha) to assess the effect of seeding rate on establishment of desirable forage. Livestock has been excluded from equal sized sections of both seeded and non-seeded portions of the study area using four strand barbed wire fence. Range enclosures were placed within the livestock excluded areas to test the effect of deer grazing on plant cover. Plant cover estimates by species will be made every other year in late summer.

## 3. Results and Discussion

Mean cover within eight blocks on the Yellow Creek habitat modification study site during 1983 was 106.1 percent, with a range of from 84.7 to 113.6 percent (Table 6-25). The entire data set is included in Appendix 6-4.1. As is evident from these data, production of forage from planted species was not accomplished on this site. Rather, a preponderance of non-planted species accounted for a very dense cover which did not afford the planted species an opportunity to become established. Non-planted forbs, including horseweed (Iva zanthifolia) and pepper-grass (Lepidium montanum), accounted for the majority of cover. In six of eight blocks non-planted forbs alone totalled over 100 percent cover and, with the overlapping canopy coverage of grasses and shrubs, all but one block had total coverages exceeding 100 percent.

Table 6-24. Species Seeded on the Yellow Creek Burn Study Site.

| Species | Seeding Rate[1/] (kg/ha) |
|---|---|
| Grasses | |
| Crested Wheatgrass | 2.2 |
| Pubescent Wheatgrass | 1.1 |
| *Western Wheatgreass | 3.4 |
| *Streambank Wheatgrass | 2.2 |
| *Russian Wildrye | 6.7 |
| Subtotal | 15.6 |
| Forbs | |
| Yellow Sweetclover | 1.1 |
| Cicer Milkvetch | 1.1 |
| Alfalfa | 3.4 |
| Subtotal | 5.6 |
| Total | 21.2 |

* Salt tolerant species

1/ Seeding rate was doubled for Blocks 5 and 7 (See Figure 6-8).

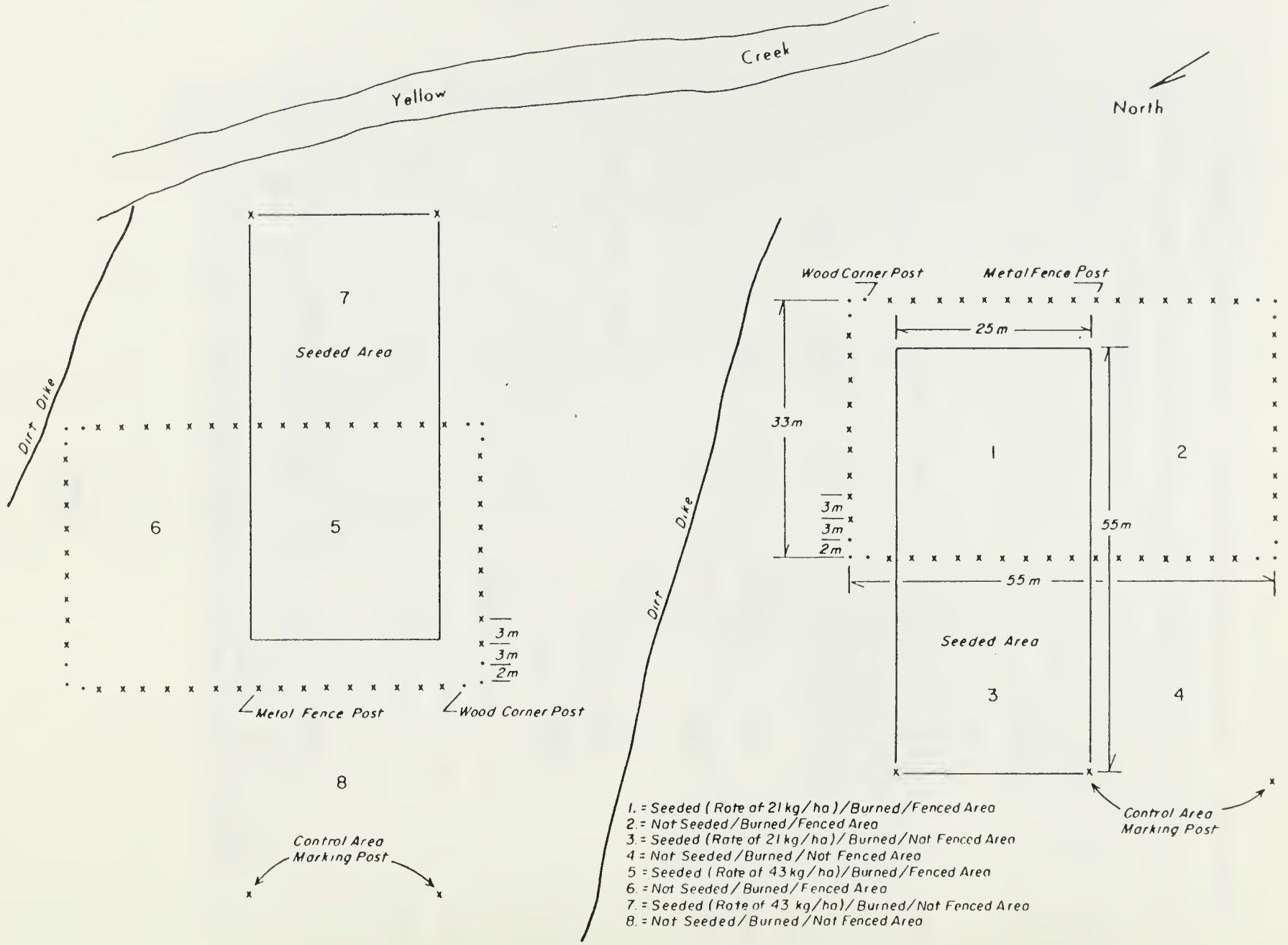



Figure 6-8. Yellow Creek Burn Area Habitat Mitigation Study Design

TABLE 6-25. MEAN VEGETATIVE COVER (%) ON THE YELLOW CREEK HABITAT MITIGATION STUDY DURING 1983.

| BLOCK[1] | GRASSES | | FORBS | | SHRUBS | | TOTAL COVER |
|---|---|---|---|---|---|---|---|
| | PLANTED | INVADED | PLANTED | INVADED | PLANTED | INVADED | |
| 1 | 15.3 | 1.9 | 0.1 | 89.8 | . | 3.6 | 110.6 |
| 2[3] | . | 32.2 | . | 50.6 | . | 1.9 | 84.7 |
| 3 | . | 1.5 | 0.6 | 101.1 | . | . | 103.3 |
| 4[2] | . | 0.5 | . | 101.4 | . | . | 101.9 |
| 5 | 4.4 | 1.9 | 1.3 | 101.0 | . | . | 108.6 |
| 6[3] | . | 10.0 | . | 102.7 | . | . | 112.7 |
| 7 | 0.1 | . | 2.0 | 111.5 | . | . | 113.6 |
| 8[2] | . | 0.6 | . | 112.6 | . | . | 113.3 |
| MEAN | 5.0 | 6.1 | 1.0 | 96.3 | . | 0.7 | 106.1 |

(1) TREATMENT COMBINATIONS FOR VARIOUS BLOCKS ARE ILLUSTRATED IN THE METHODS SECTION AND THE COMPLETE DATA SET IS AVAILABLE IN THE APPENDIX.

(2) CONTROL AREAS WHICH RECEIVED NO TREATMENTS

(3) TREATMENT AREAS WHICH RECEIVED NO SEEDING

The phenomenon experienced on the Yellow Creek burn site suggests that fire alone is not an adequate measure to reduce cover of undesirable species. In this instance seed from horseweed and other rank forb species was undoubtedly present prior to the fire. Once the competition from the sagebrush had been removed via burning, the seed of non-planted species germinated in abundance. Competition from these non-planted species suppressed those species which had been planted. One possible solution would be to allow the non-planted species to become established the first year after burning and then suppress them with herbicides prior to planting more desireable species.

Because of the paucity of planted species, statistical testing of variations in cover among blocks, as well as between caged (deer excluded) and uncaged plots within fenced areas, was deferred. If subsequent sampling of the site provides sufficient replication of planted species, statistical comparisons may be warranted.

## 6.5 COMPARISON STUDY OF INHALABLE AND TOTAL SUSPENDED PARTICULATES

### 1. Objectives

Many investigations have shown that the current Total Suspended Particulate (TSP) National Ambient Air Quality Standard does not directly address health-related concerns. The major reason for this is that particles collected by TSP monitors have diameters up to a maximum of approximately 30-50 μm, whereas particles with diameters larger than 10 to 15 μm are excluded from the body by natural defense mechanisms in the respiratory system. At the same time, the larger particles have an inordinately large influence on a gravimetric sampling technique such as used for TSP, since the mass of a particle is generally proportional to the third power of the radius of a particle.

As a result, EPA is currently in the process of changing the present TSP standard to a more health-related inhalable particulate standard. The new standard will probably have a 50 percent particle cutpoint (or rejection point) at 10 μm, and will be referred to as $PM_{10}$.

In order to determine the impact of a possible new standard on our permitting activities, and to be able to intelligently comment on any proposed regulation, $PM_{10}$ monitors were installed at the existing sites toward the end of 1982.

### 2. Methods

One $PM_{10}$ monitor was colocated with each of the existing TSP monitors at Sites 1 and 3. These $PM_{10}$ samplers are standard Hi-Vol monitors modified with a Wedding $PM_{10}$ inlet. The monitors became operational in 1982.

3. Results and Discussion

One year's TSP and $PM_{10}$ data taken from colocated samplers at Tract C-a are now available for comparison. Table 6-26 provides a listing of these data for 1983. Seasonal and annual geometric means of the data are given in Table 6-27. This table shows that the ratio of $PM_{10}$ to TSP concentration, based on the annual geometric mean, is 0.46 at Site 1 and 0.49 at Site 3.

However, these ratios must be used very cautiously, since approximately 60 percent of the observations at the two sites had TSP concentrations at or below 10 $g/m^3$. At the lower concentrations, the inherent inaccuracies of the measurement system became relatively more important and may bias the results.

Another important factor to be considered is a modification that was made to the $PM_{10}$ monitors: on July 14, 1983 the monitors were returned to the manufacturer to install an oil-based particle absorbing material in the inlet. The objective of this modification was to reduce the possibility of particle bounce and reentrainment in the inlet by retaining those particles striking the walls of the inlet, thereby improving the efficiency of the monitor in excluding large particles.

Consequently, the analysis of the data was redone using only days in which the TSP concentrations exceeded 10 $g/m^3$. The data set was also subdivided into two categories - data taken before and after the inlet modification (July 14). The results for the two sites are presented in Tables 6-28 and 6-29. The mean ratio of $PM_{10}$ to TSP concentrations at Site 1 (for concentrations greater than 10 $g/m^3$) is 0.58 before July 14 and 0.38 after July 14. The mean ratio at Site 3 is 0.60 before July 14 and 0.38 after July 14. Based upon the T-test, these means are significantly different at the 99 percent confidence level.

TABLE 6-26. INHALABLE AND TOTAL SUSPENDED PARTICULATE CONCENTRATIONS FOR 1983.

| | SITE 1 | | SITE 3 | |
|---|---|---|---|---|
| DATE | TSP | IP-10 | TSP | IP-10 |
| 04JAN83 | 4 | 2 | 1 | . |
| 08JAN83 | 5 | 3 | 5 | 2 |
| 12JAN83 | 3 | 2 | 1 | 0 |
| 16JAN83 | 8 | 8 | 6 | 3 |
| 20JAN83 | . | . | 5 | 2 |
| 24JAN83 | 5 | 4 | 4 | 3 |
| 28JAN83 | . | . | 6 | 3 |
| 01FEB83 | 5 | 4 | 5 | 3 |
| 05FEB83 | . | 8 | 8 | 5 |
| 09FEB83 | 3 | 2 | 3 | 1 |
| 13FEB83 | 6 | 4 | 4 | . |
| 17FEB83 | 4 | 2 | 3 | 2 |
| 21FEB83 | 5 | 3 | 5 | 3 |
| 25FEB83 | 10 | 7 | 7 | 4 |
| 01MAR83 | 7 | 0 | 2 | 2 |
| 05MAR83 | 4 | 3 | 4 | 2 |
| 09MAR83 | 5 | . | 4 | 2 |
| 13MAR83 | 4 | 4 | 5 | 4 |
| 17MAR83 | 5 | 3 | 4 | 3 |
| 21MAR83 | 6 | 3 | 4 | 2 |
| 25MAR83 | 4 | 3 | 5 | 4 |
| 29MAR83 | 5 | 4 | 3 | 2 |
| 02APR83 | . | 3 | 3 | 2 |
| 06APR83 | 9 | 6 | 7 | 4 |
| 10APR83 | 16 | 12 | 14 | 10 |
| 14APR83 | 9 | 6 | 7 | 4 |
| 18APR83 | 17 | 10 | 18 | 11 |
| 22APR83 | 5 | . | 4 | 2 |
| 26APR83 | 8 | 4 | 9 | 5 |
| 30APR83 | 3 | 2 | 2 | 1 |
| 04MAY83 | 20 | 4 | 6 | 4 |
| 08MAY83 | . | 9 | 14 | 9 |
| 12MAY83 | 10 | 4 | 9 | 3 |
| 16MAY83 | . | . | 2 | 1 |
| 20MAY83 | 8 | 2 | 5 | 3 |
| 24MAY83 | . | . | 14 | 9 |
| 28MAY83 | 22 | 15 | 17 | 12 |
| 01JUN83 | 19 | 12 | 26 | 16 |
| 05JUN83 | 4 | 2 | 9 | 4 |
| 09JUN83 | 11 | 7 | 11 | 7 |
| 13JUN83 | 8 | 3 | 7 | 3 |
| 17JUN83 | 17 | 11 | 17 | 10 |
| 21JUN83 | 33 | 18 | 28 | 17 |
| 25JUN83 | 10 | 5 | 14 | 7 |
| 29JUN83 | 25 | 16 | 25 | 8 |
| 03JUL83 | 15 | 8 | 20 | 12 |

TABLE 6-26. INHALABLE AND TOTAL SUSPENDED PARTICULATE CONCENTRATIONS FOR 1983.

| | SITE 1 | | SITE 3 | |
|---|---|---|---|---|
| DATE | TSP | IP-10 | TSP | IP-10 |
| 07JUL83 | 20 | 12 | 24 | 14 |
| 11JUL83 | 18 | 9 | 19 | 11 |
| 15JUL83 | 46 | . | 54 | . |
| 19JUL83 | 19 | . | 23 | . |
| 23JUL83 | 11 | . | 11 | . |
| 27JUL83 | 17 | 4 | 13 | 5 |
| 31JUL83 | 14 | 5 | 14 | 9 |
| 04AUG83 | 21 | 8 | 32 | 12 |
| 08AUG83 | 92 | 29 | 56 | 22 |
| 12AUG83 | 11 | 5 | 12 | . |
| 16AUG83 | 14 | 7 | 17 | 7 |
| 20AUG83 | 12 | 4 | 33 | 13 |
| 24AUG83 | 14 | 7 | 25 | 9 |
| 28AUG83 | 22 | 7 | 21 | 7 |
| 01SEP83 | 18 | 6 | 16 | 7 |
| 05SEP83 | 10 | 7 | 14 | 5 |
| 09SEP83 | 21 | 7 | 24 | 8 |
| 13SEP83 | 16 | 6 | 31 | 9 |
| 17SEP83 | 27 | 8 | 49 | 15 |
| 21SEP83 | 13 | . | 17 | . |
| 25SEP83 | 10 | 4 | . | . |
| 29SEP83 | 8 | 3 | 8 | 2 |
| 03OCT83 | 5 | 3 | 4 | 9 |
| 07OCT83 | 7 | 5 | 10 | 3 |
| 11OCT83 | 4 | 1 | 6 | 2 |
| 15OCT83 | . | 3 | 5 | 5 |
| 19OCT83 | 7 | 2 | 6 | 3 |
| 23OCT83 | 10 | 6 | 18 | 7 |
| 27OCT83 | 12 | 6 | 25 | 9 |
| 31OCT83 | 17 | 10 | . | 8 |
| 04NOV83 | 8 | 5 | 18 | 6 |
| 08NOV83 | 2 | 3 | 4 | . |
| 12NOV83 | 8 | 3 | 6 | 4 |
| 16NOV83 | 7 | 5 | 7 | 1 |
| 20NOV83 | 4 | 0 | 2 | 0 |
| 24NOV83 | 2 | 1 | 4 | 1 |
| 28NOV83 | . | 1 | 5 | 1 |
| 02DEC83 | 4 | 2 | 5 | 3 |
| 06DEC83 | 6 | 2 | 5 | 2 |
| 10DEC83 | 6 | 4 | 5 | 3 |
| 14DEC83 | 0 | 0 | 3 | 0 |
| 18DEC83 | 7 | 5 | 5 | 4 |
| 22DEC83 | 7 | 4 | 6 | 3 |
| 26DEC83 | 0 | 0 | 2 | 1 |
| 30DEC83 | . | 1 | 2 | 1 |

Table 6-27. Quarterly and Annual Geometric Means and Maximum Values of 24-hour Average TSP and $PM_{10}$ Concentrations ($ug/m^3$) during 1983 on Tract C-a.

| | Site 1 | | Site 3 | |
|---|---|---|---|---|
| | TSP | $PM_{10}$ | TSP | $PM_{10}$ |
| Winter 1983 (Jan, Feb, Mar) | | | | |
| Geometric Mean | 4 | 3 | 4 | 2 |
| Maximum | 10 | 8 | 8 | 5 |
| Spring 1983 (Mar - May) | | | | |
| Geometric Mean | 7 | 4 | 6 | 3 |
| Maximum | 22 | 15 | 18 | 12 |
| Summer 1983 (Jun- Aug) | | | | |
| Geometric Mean | 17 | 7 | 19 | 9 |
| Maximum | 92 | 29 | 56 | 22 |
| Fall 1983 (Sep-Nov) | | | | |
| Geometric Mean | 8 | 3 | 10 | 4 |
| Maximum | 27 | 10 | 49 | 15 |
| 1983 Annual | | | | |
| Geometric Mean | 9 | 4 | 8 | 4 |
| Maximum | 92 | 29 | 56 | 22 |

Table 6-28. Comparison of $PM_{10}$ and TSP Calculated Data (for TSP>10 ug/$m^3$) from Site 1 During 1983, Subdivided Into Periods Before and After Inlet Modification to $PM_{10}$ Monitor (July 14)

Site 1

| Before July 14 | | | | After July 14 | | | |
|---|---|---|---|---|---|---|---|
| Date | TSP Concentration | $PM_{10}$ Concentration | Ratio of $PM_{10}$/TSP | Date | TSP Concentration | $PM_{10}$ Concentration | Ratio of $PM_{10}$/TSP |
| 6/21 | 33 | 18 | 0.55 | 8/08 | 92 | 29 | 0.32 |
| 6/29 | 25 | 16 | 0.64 | 9/17 | 27 | 8 | 0.30 |
| 5/28 | 22 | 15 | 0.68 | 8/28 | 22 | 7 | 0.32 |
| 7/7 | 20 | 12 | 0.60 | 9/09 | 21 | 7 | 0.32 |
| 5/4 | 20 | 4 | 0.20 | 8/04 | 21 | 8 | 0.38 |
| 6/1 | 19 | 12 | 0.63 | 9/01 | 18 | 6 | 0.33 |
| 7/11 | 18 | 9 | 0.50 | 10/31 | 17 | 10 | 0.59 |
| 6/17 | 17 | 11 | 0.65 | 7/27 | 17 | 4 | 0.24 |
| 4/18 | 17 | 10 | 0.59 | 9/13 | 16 | 6 | 0.38 |
| 4/10 | 16 | 12 | 0.75 | 8/16 | 14 | 7 | 0.50 |
| 7/3 | 15 | 8 | 0.53 | 8/24 | 14 | 7 | 0.50 |
| 6/9 | 11 | 7 | 0.64 | 7/31 | 14 | 5 | 0.36 |
| | | | | 10/27 | 12 | 6 | 0.50 |
| | | | | 8/20 | 12 | 4 | 0.33 |
| | | | | 8/12 | 11 | 5 | 0.45 |
| Mean | | | 0.58 | | | | 0.39 |

Table 6-29. Comparison of $PM_{10}$ and TSP Calculated Data (for TSP>10 ug/$m^3$) from Site 3 During 1983, Subdivided Into Periods Before and After Inlet Modification to $PM_{10}$ Monitor (July 14)

Site 3

| Before July 14 | | | | After July 14 | | | |
|---|---|---|---|---|---|---|---|
| Date | TSP Concentration | $PM_{10}$ Concentration | Ratio of $PM_{10}$/TSP | Date | TSP Concentration | $PM_{10}$ Concentration | Ratio of $PM_{10}$/TSP |
| 6/21 | 28 | 17 | 0.61 | 8/08 | 56 | 22 | 0.39 |
| 6/01 | 26 | 16 | 0.62 | 9/17 | 49 | 15 | 0.31 |
| 6/29 | 25 | 8 | 0.32 | 8/20 | 33 | 13 | 0.39 |
| 7/07 | 24 | 14 | 0.58 | 8/04 | 32 | 12 | 0.38 |
| 7/03 | 20 | 12 | 0.60 | 9/13 | 31 | 9 | 0.29 |
| 7/11 | 19 | 11 | 0.58 | 8/24 | 25 | 9 | 0.36 |
| 4/18 | 18 | 11 | 0.61 | 10/27 | 25 | 9 | 0.36 |
| 5/28 | 17 | 12 | 0.71 | 9/09 | 24 | 8 | 0.33 |
| 6/17 | 17 | 10 | 0.59 | 8/28 | 21 | 7 | 0.33 |
| 4/10 | 14 | 10 | 0.71 | 10/23 | 18 | 7 | 0.39 |
| 5/08 | 14 | 9 | 0.64 | 11/04 | 18 | 6 | 0.33 |
| 6/25 | 14 | 7 | 0.50 | 8/16 | 17 | 7 | 0.41 |
| 5/24 | 14 | 9 | 0.64 | 9/01 | 16 | 7 | 0.44 |
| 6/09 | 11 | 7 | 0.64 | 9/05 | 14 | 5 | 0.36 |
| | | | | 7/31 | 14 | 9 | 0.64 |
| | | | | 7/27 | 13 | 5 | 0.38 |
| Mean | | | 0.60 | | | | 0.38 |

Since the mean ratio of $PM_{10}$ to TSP concentrations dropped after the inlet modifications, it can be inferred that the modification improved the ability of the $PM_{10}$ monitor to reject large particles. A good estimate of the relationship between $PM_{10}$ and TSP at Tract C-a, based upon this year's data, is that $PM_{10}$ concentrations average about 40 percent of the TSP concentrations.

## 6.6 SUMMARY

### A. Revegetation

#### 1. Experimental Revegetation on Surface Disturbed Sites

Experimental Revegetation Plot R-1, located on a northwestern exposure at 2164 M (7100 ft), had an average vegetative cover of 85.2 percent for all species over the sixteen treatment combinations tested. This represented a marked increase over the 50 percent cover recorded during 1982 and was probably the result of increased precipitation during the growing season.

Planted wheatgrass (Agropyron) species continued to provide the majority of cover for planted grasses, with green needlegrass (Stipa viridula) and Indian ricegrass (Oryzopsis hymenoides) being subordinate species. Planted grasses accounted for an average of 41.9 percent cover in 1983 whereas invader species averaged 7 percent. A statistical comparison of 1983 cover data for planted and invader grasses between treatment combinations revealed only one significant difference, that being associated with mulch treatments. Invader grass species on the no mulch treatment had significantly higher cover than areas with straw mulch held in place by crimping. This relationship had not been noted in analyses from recent years and it is unclear why this particular effect of mulch treatments became evident in these data. Grass cover for planted species in 1983 was found to be significantly higher than for all other years of record, whereas cover of invader species was similar to that recorded in all years except 1977 and 1978.

Cover of planted forb species was 23.8 percent during 1983, which presented an increase from 16.1 percent recorded in 1982. Invader species increased only slightly, from 3.4 in 1982 to 4.5 percent in 1983. Comparisons of forb cover among treatment combinations for 1983 data showed no significant differences based on mulch or fertilizer amendments. The fact that differences were evident when data for all years were used in statisticaal

comparisons supports the supposition that effects are imparted primarily during years shortly after mulching and/or fertilization. When forb cover was compared among years without regard to treatment combinations, cover of planted forb species, primarily cicer milkvetch (Astragalus cicer), Lewis flax (Linum lewisii), and yellow sweetclover (Melilotus officinalis) was significantly higher in 1983 than for any other sample period.

Cover of planted shrub species increased from 4.4 percent in 1982 to 7.3 percent in 1983. No significant differences were evident among treatment combinations based on 1983 data. As noted for grasses and forbs, cover of planted shrubs on Plot R-1 was significantly higher in 1983 relative to the other six years of record. Big sagebrush (Artemisia tridentata), winterfat (Ceratoides lanata) and rubber rabbitbush (Chrysothamnus nauseosus) continued to be the prominent contributors to shrub cover.

Cover for all species over all treatment combinations on Plot R-2 was 62.0 percent. As noted for Plot R-1, this represented a substantial increase relative to 1982 when cover averaged 38.6 percent. The lower cover on Plot R-2 as compared to Plot R-1 was probably related to variations in slope aspect. The southerly exposure of Plot R-2 was expected to receive greater insolation than at Plot R-1, which in turn would result in higher evapotranspiration and reduced plant available moisture.

Wheatgrass species and Indian ricegrass were the main contributors to cover of planted grasses, which averaged 21.8 percent for 1983. Cover of invader grass species also increased relative to 1982 (2.7 versus 1.6%). No significant differences in cover among mulch and fertilizer amendents were noted for either planted or invader species during 1983. However, minor differences were noted in cover of invader grasses among block replicates. Cover of planted grass species was significantly higher in 1983 than for the previous six years whereas cover of invader species for 1983 was higher than all sample periods except 1976.

Cicer milkvetch and Lewis flax were the primary contributors to cover of planted forb species, which averaged 15.1 percent during 1983. Cover of invader forb species increased only slightly in 1983 relative to 1982 (2.2 versus 1.9%). Based on 1983 data, no significant effects were noted relative to either mulch or fertilizer treatments. However, significant differences among years were evident, with cover of planted forbs being significantly higher in 1983 than for all other sample periods. Cover of invader forb species during 1983 was similar to all other years except 1977 and 1978 when cover of invaders was significantly higher.

Rubber rabbitbrush, winterfat and fourwing saltbush (Atriplex canescens) were the primary contributors to cover of planted shrub species which averaged 18.9 percent during 1983. Broom snakeweed (Gutierrezia sarothrae) was the only invader species encountered, with cover averaging 1.2 percent. No significant differences in cover among mulch or fertilizer treatments were noted during 1983.

Conclusions regarding the use of mulch and/or fertilizer for RBOSC revegetation efforts, as based on studies at Plots R-1 and R-2, were discussed in MDP Monitoring Report 11 (RBSOC 1983) and were not altered by the 1983 results. However, the increased cover of grasses, forbs and shrubs in 1983, apparently due largely to increased and more uniform precipitation, illustrated that planted species may form rather closed stands of vegetation given adequate moisture. This was particularly true for perennial grasses which seemed to respond rapidly to the uniform precipitation throughout the 1983 growing season. When closed stands are formed by highly competitive species, the movement of invader species from surrounding plant communities into revegetated areas is inhibited. Because invader species can be beneficial to revegetation efforts by increasing species richness, management techniques such as grazing of reclaimed sites may prove useful in long term maintenance of revegetated areas.

2. Experimental Revegetation on a Simulated Processed Shale Disposal Site

Cover of grass, forb and shrub species averaged over all treatment combinations on Plot R-3 was 63.7 percent on the control (no processed shale) portion of the plot and 64.9 percent on the treatment (underlain by processed shale) side.

Planted grasses accounted for 26 percent cover for all treatment combinations while invader species contributed 10.4 percent cover. Wheatgrass species continued to be the predominant planted species, whereas crested wheatgrass and cheatgrass (Bromus tectorum) were the more abundant invader sepcies. No significant differences in cover of all invader or all planted grasses among treatments were noted during 1983. However, invader grasses provided significantly more cover during 1983 than during any of the five previous sample periods. Although the cover of planted grasses in 1983 was not significantly different from that of 1979 or 1980, the increase from 1982 to 1983 was shown to be significant.

Cover of planted forbs averaged 10.6 percent over all treatment combinations during 1983, which is the highest cover noted since estimates began in 1977. Invader forb species contributed an average of only 0.4 percent cover during 1983. Statistical comparisons of forb cover showed no differences between the treatment combinations tested. Cicer milkvetch, the dominant planted forb species, appeared to be able to compete favorably with planted grasses and shrubs; however, most other forbs have not done nearly as well. Using additional, more competitive forb species or reducing the seeding rates for wheatgrass species would improve the success of forb species.

Planted shrub species, primarily winterfat and fourwing saltbush, contributed 16.1 percent cover averaged over all treatments on Plot R-3. This represents a slight increase in cover relative to 1982. Invader species accounted for an additional 0.8 percent cover, which was a slight decrease from the 1 percent recorded in 1982. When all planted shrub species were grouped together, statistical tests comparing cover among

treatment combinations showed no significant differences. Significant variations in cover of shrubs among years were evident. Shrub cover for 1983, 1982 and 1979 was similar; however, these three years had cover significantly higher than all other sample periods.

Monitoring of moisture within the reconstructed soil profile or processed shale on Plot R-3 using a neutron probe moisture gauge seemed to show that the quantity of moisture available in the spring was sufficient to result in movement throughout the profile, as well as into the processed shale. However, measurements also documented an apparent depletion of moisture from the profile during the growing season, probably due to capillary rise and/or transpiration from plants. Statistical comparisons of moisture data revealed significant differences between substrates for the second half of the growing season, among slope positions for the first three months, and among depths for all six months of record. The combination of substrate and depth differences seemed to indicate slower movement of moisture into the processed shale than into overburden material at a similar depth in the reconstructed profile, which is consistent with variations in density between the processed shale and overburden.

B. Mule Deer Habitat Modification Study

The mule deer habitat modification study site testing brush removal via rotochopping was not sampled during the 1983 field season. Subsequent sampling will be accomplished as per the Scope of Work.

C. Shrub Growth Enhancement on a Simulated Mine Site and/or Disposal Pile Bench

1. Shrub Survival

Of the seven species planted, New Mexico black locust (Robinea neomexicana) was the only species with 100 percent survival. The lowest survial rate recorded was for serviceberry (Amelanchier alnifolia). Most species, with

the exception of serviceberry and fourwing saltbush (two palatable species), exhibited similar survival rates on both the browsed and deer excluded portions of the study site. Among the five rows of shrubs, Row C on the bench per se exhibited the highest survival rate. However, this row did not appear to have received the greatest amount of moisture as based on neutron probe readings.

2. Shrub Growth

The greatest growth, as indicated by plant height-plant diameter indices, was achieved by fourwing saltbush and New Mexico black locust. In the 15-month interval between planting and measurements taken in September 1983, these species attained approximately 50 percent of the growth necessary for them to afford protection to wildlife. Individuals of both species were somewhat older than those of the five other species at the time of planting and this may have offered a competitive advantage. As with differential survival of the various species tested, serviceberry had the poorest growth of the seven shrub species.

Although several growing seasons are required before substantive conclusions can be drawn, data collected thus far seemed to dictate that growth of shrubs on the simulated mine/disposal pile bench was not influenced significantly by either topsoil, browsing or potentially increased moisture.

3. Soil Moisture

Moisture in surface soils (0-25 cm) appeared to decrease from May through September and then increase slightly in October. This pattern occurred in all five rows on the bench and was not unexpected given variations in temperature, precipitation, and evapotranspiration throughout the growing season. Moisture appeared to be the highest in Row E but there was no significant difference in moisture (0-25 cm) between Rows B, C or E. Highest "moisture" corresponded to the row with the lowest survival. Furthermore, growth indices did not correspond with areas of highest

apparent "moisture". Measurements on the bench may be biased by the shale substrate and may reflect relative total moisture more accurately than they do plant available moisture. Studies to date have not confirmed that moisture has been effectively "harvested".

D. Study to Alter Natural Succession after Fire for Enhanced Deer-Livestock Forage

Mean cover within eight blocks on the Yellow Creek habitat modification study site during 1983 was 106.1 percent. Production of forage from planted species was not accomplished. Rather, a preponderance of non-planted species accounted for a very dense cover which did not afford the planted species an opportunity to become established. Results of this study indicate that fire alone is not an adequate measure to reduce cover of undesirable species. One possible alternative would be to allow the non-planted species to become established the first year after burning and then suppress them with herbicides prior to planting more desireable species.

E. Comparison of Inhalable and Total Suspended Particulates

$PM_{10}$ monitors (Hi-Vols fitted with Wedding $PM_{10}$ inlets) were colocated at Sites 1 and 3 with TSP monitors. The mean ratio of $PM_{10}$ concentration to TSP concentrations during 1983 was 0.46 at Site 1 and 0.49 at Site 3. However, the $PM_{10}$ monitors were modified in July by putting an oil-based particle absorbing material in the inlet to reduce the possibility of particle bounce and reentrainment. The mean ratios of $PM_{10}$ to TSP concentrations were recalculated for the data collected after the inlet modification (also excluding data where TSP concentrations were less than 10 $g/m^3$ to reduce the uncertainties inherent at low concentrations). These ratios, which are probably more representative, were approximately 0.40 at both sites.

## LITERATURE CITED


Rio Blanco Oil Shale Project. 1975. Quarterly progress report 4. Gulf Oil Corp. and Standard Oil Co. (Indiana).

Rio Blanco Oil Shale Company. 1977. Revegetation program 1976 annual report. Gulf Oil Corp. and Standard Oil Co. (Indiana).

_____. 1978. Revegetation program 1977 annual report. Gulf Oil Corp. and Standard Oil Co. (Indiana).

_____. 1979. Revegetation program 1978 annual report. Gulf Oil Corp. and Standard Oil Co. (Indiana).

_____. 1980. Modular development phase monitoring report 5. Gulf Oil Corp. and Standard Oil Co. (Indiana).

_____. 1981. Modular development phase monitoring report 7, December 1979 - November 1980. Gulf Oil Corp. and Standard Oil Co. (Indiana).

_____. 1982. Modular development phase monitoring report 9, December 1980 - December 1981. Gulf Oil Corp. and Standard Oil Co. (Indiana).

_____. 1983. Modular development phase monitoring report 11, January 1982 - December 1982. Gulf Oil Corp. and Standard Oil Co. (Indiana).

Wright, H.A., L.F. Neunschwander, and C.M. Britton. 1979. The role and use of fire in sagebrush-grass and pinyon-juniper plant communities, a state of the art review. USDA-Forest Service general technical report INT-58.

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